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Sills et al.

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(54) **METHODS OF FABRICATING A CROSS POINT MEMORY ARRAY**

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H01L 23/52 (2006.01)

(52) **U.S. Cl.** **438/3**; 438/129; 257/211; 257/296; 257/E29.17

(58) **Field of Classification Search** None
See application file for complete search history.

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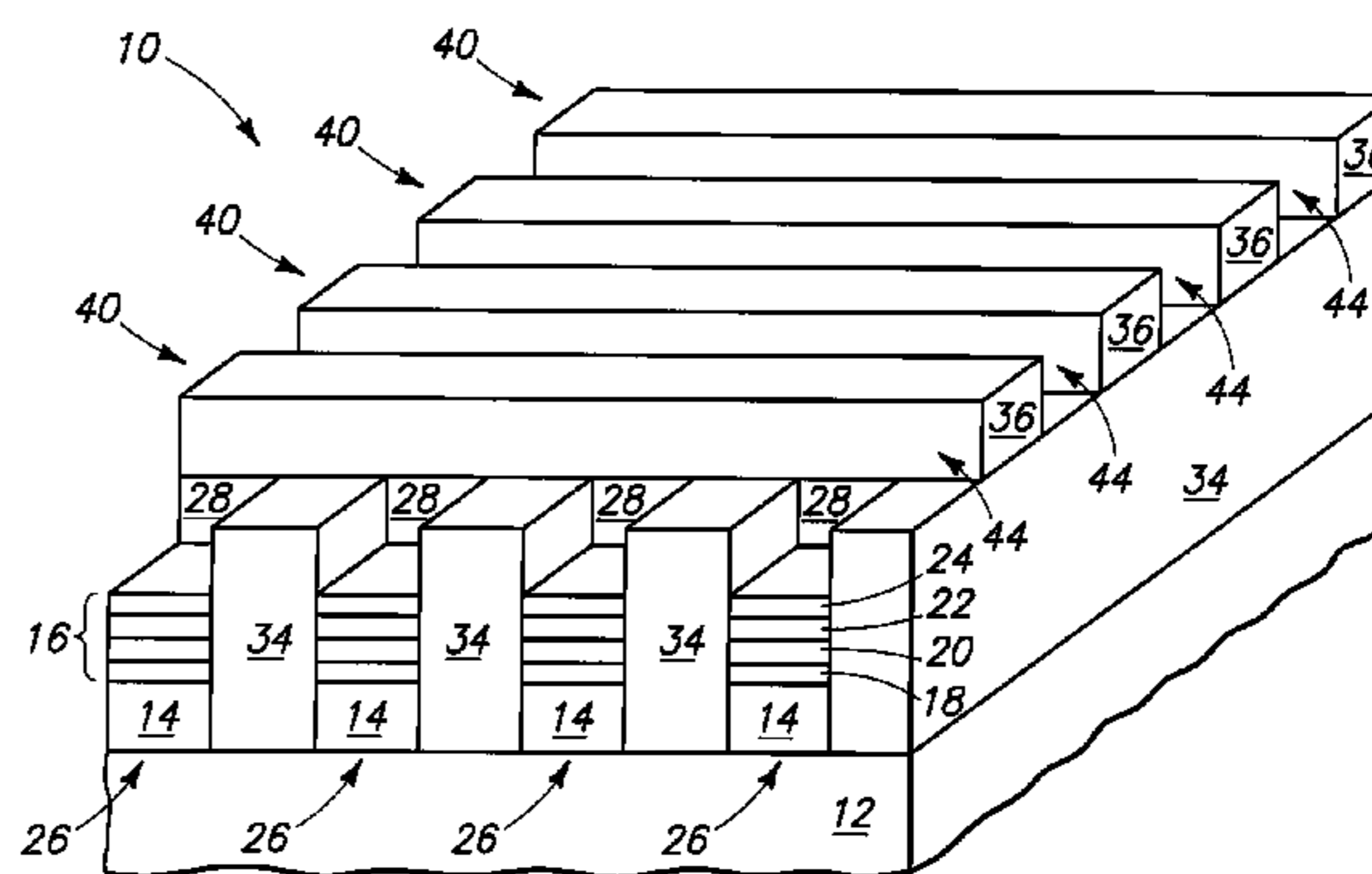
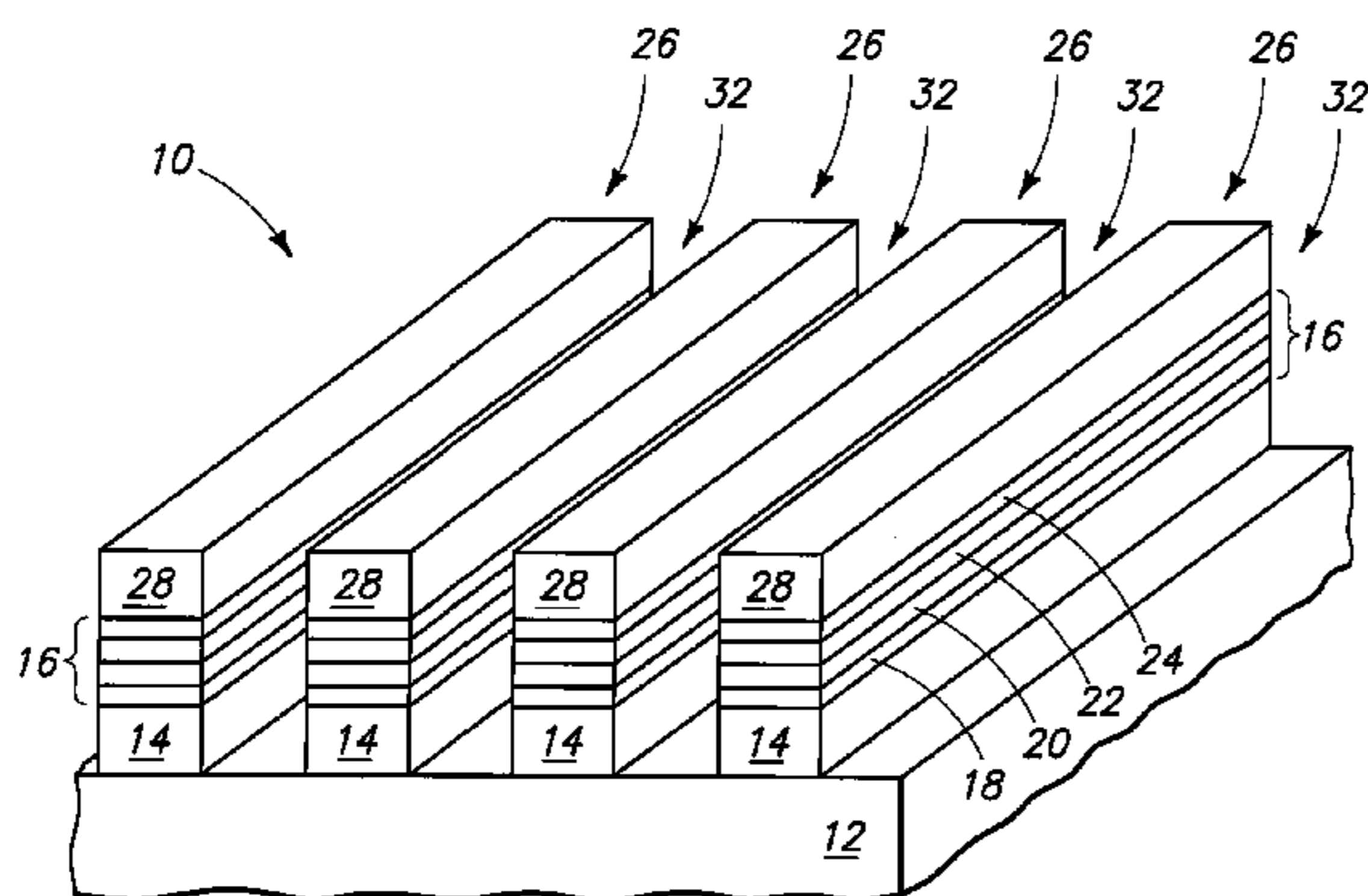
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(57) **ABSTRACT**

Some embodiments include cross-point memory structures. The structures may include a line of first electrode material extending along a first horizontal direction, a multi-sided container of access device materials over the first electrode material, a memory element material within the multi-sided container, and a line of second electrode material over the memory element material and extending along a second horizontal direction that is orthogonal to the first horizontal direction. Some embodiments include methods of forming memory arrays. The methods may include forming a memory cell stack over a first electrode material, and then patterning the first electrode material and the memory cell stack into a first set of spaced lines extending along a first horizontal direction. Spaced lines of second electrode material may be formed over the first set of spaced lines, and may extend along a second horizontal direction that is orthogonal to the first horizontal direction.

27 Claims, 26 Drawing Sheets



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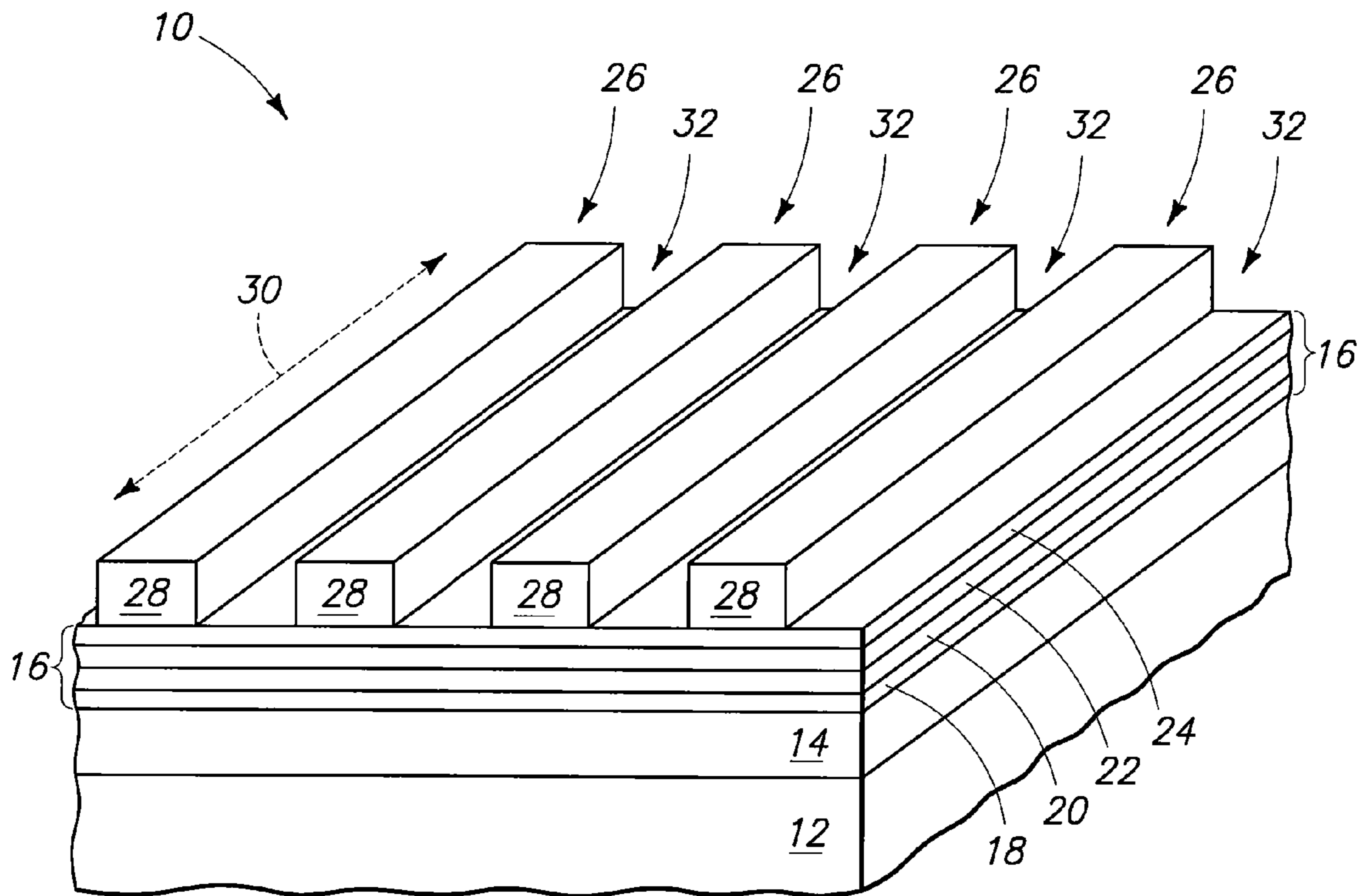


FIG. 1

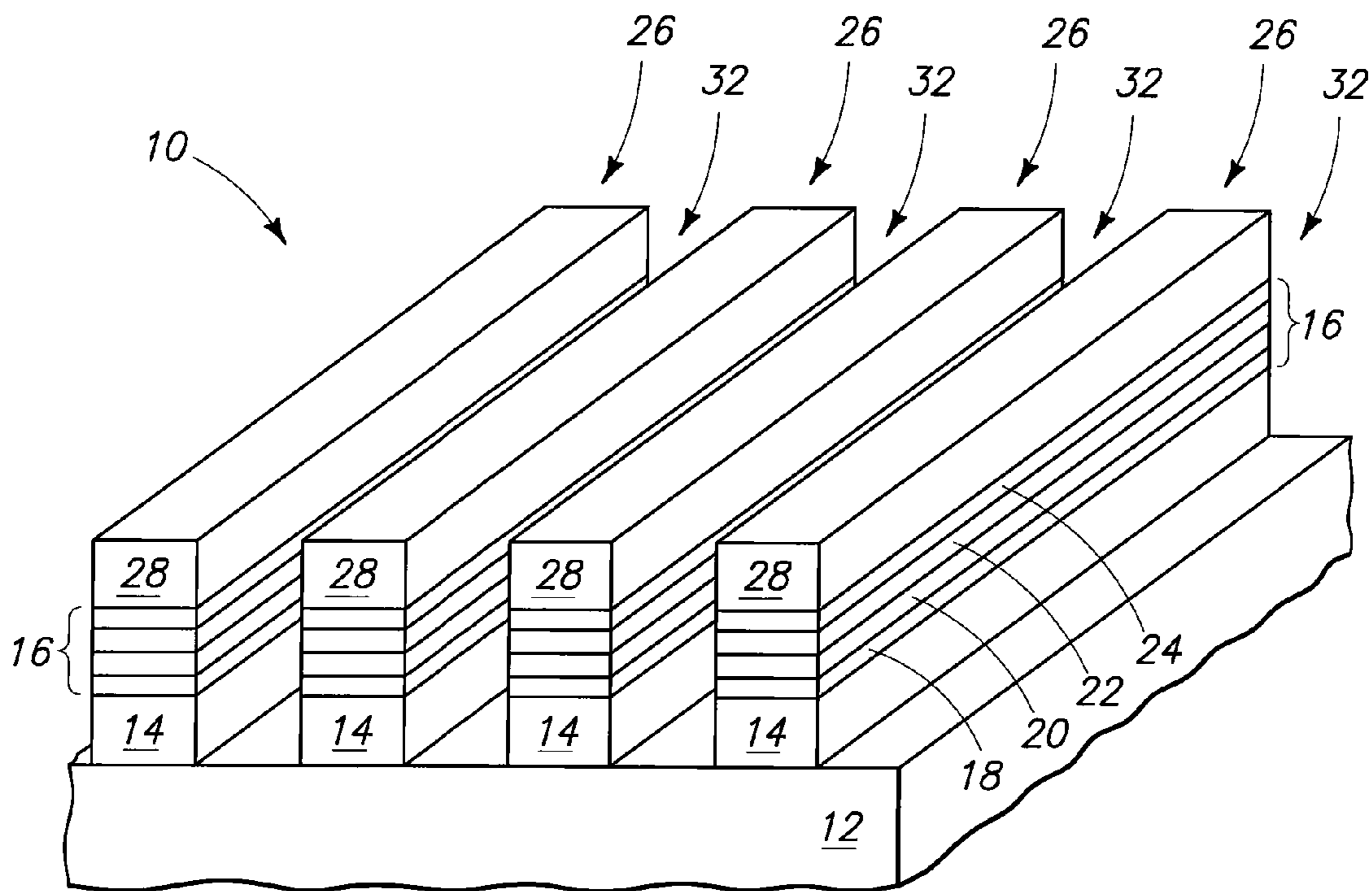


FIG. 2

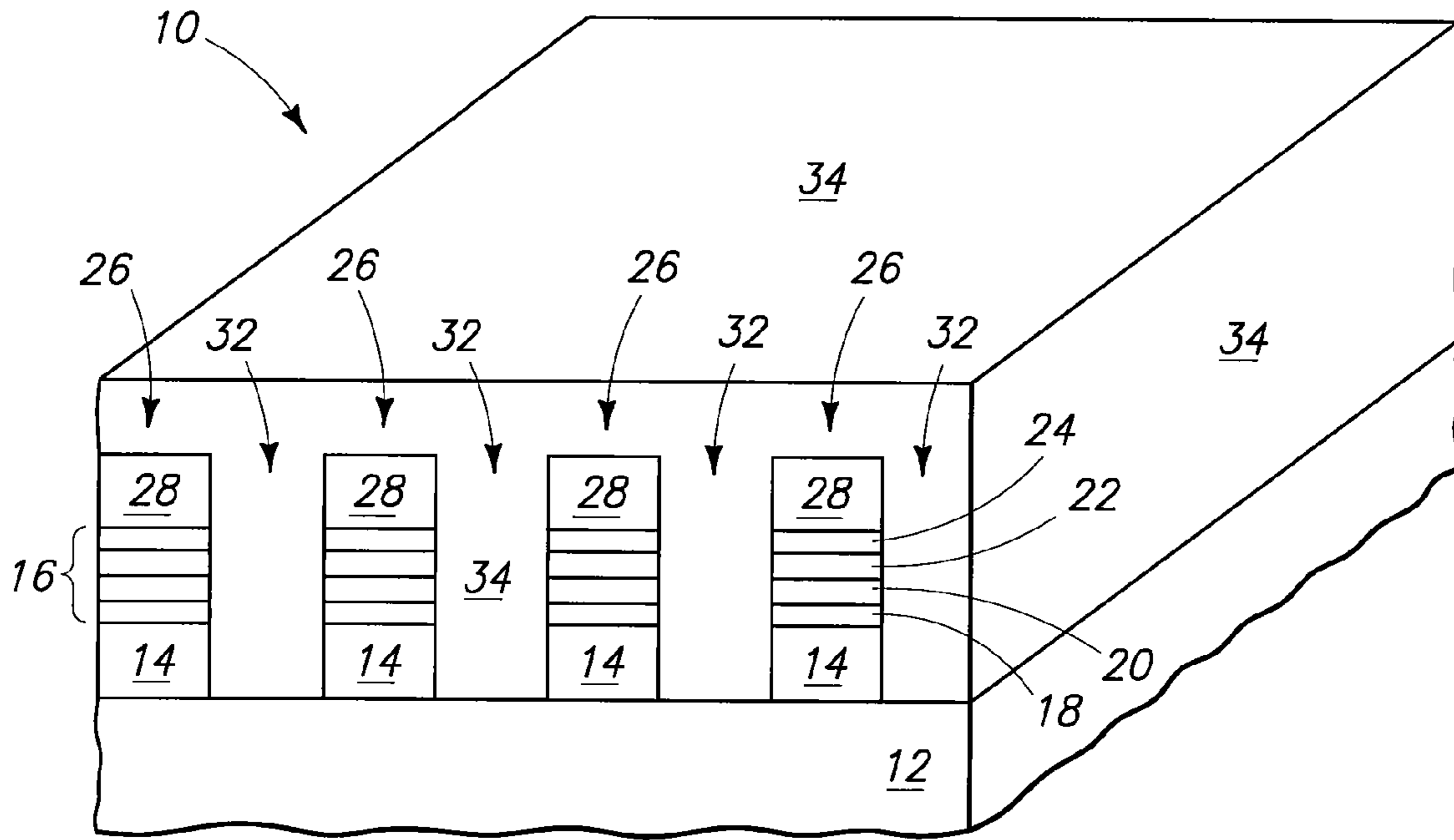


FIG. 2

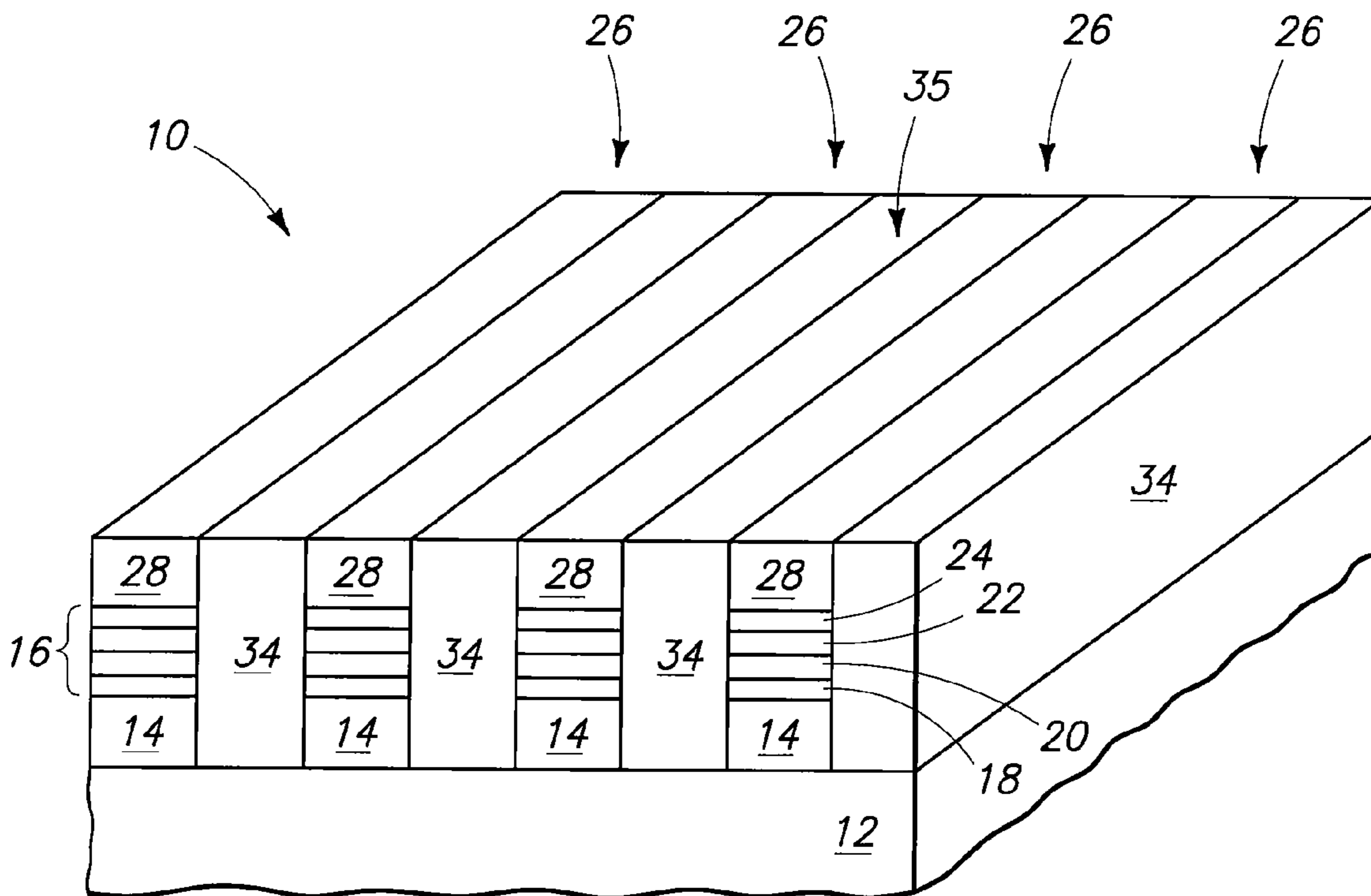
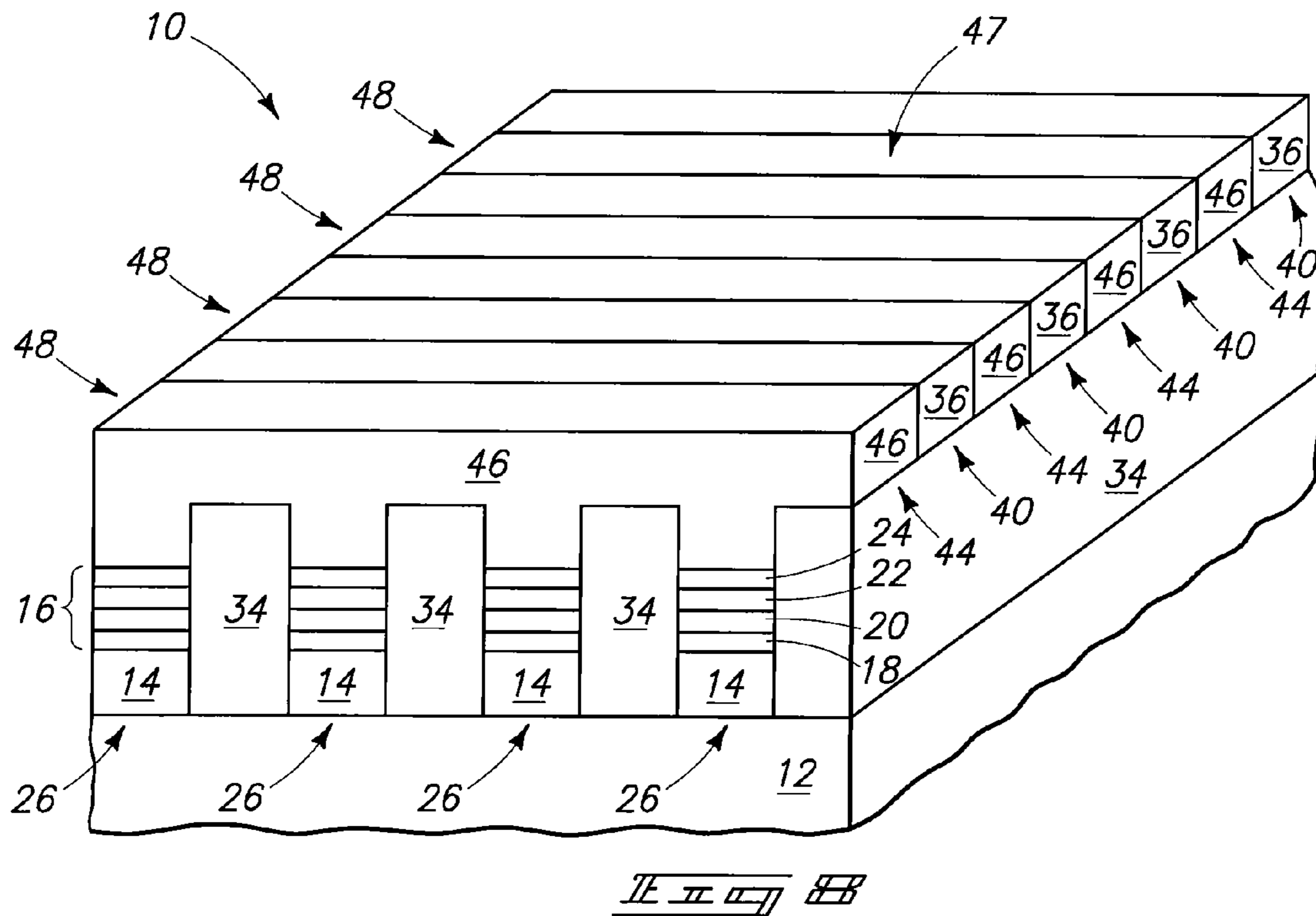
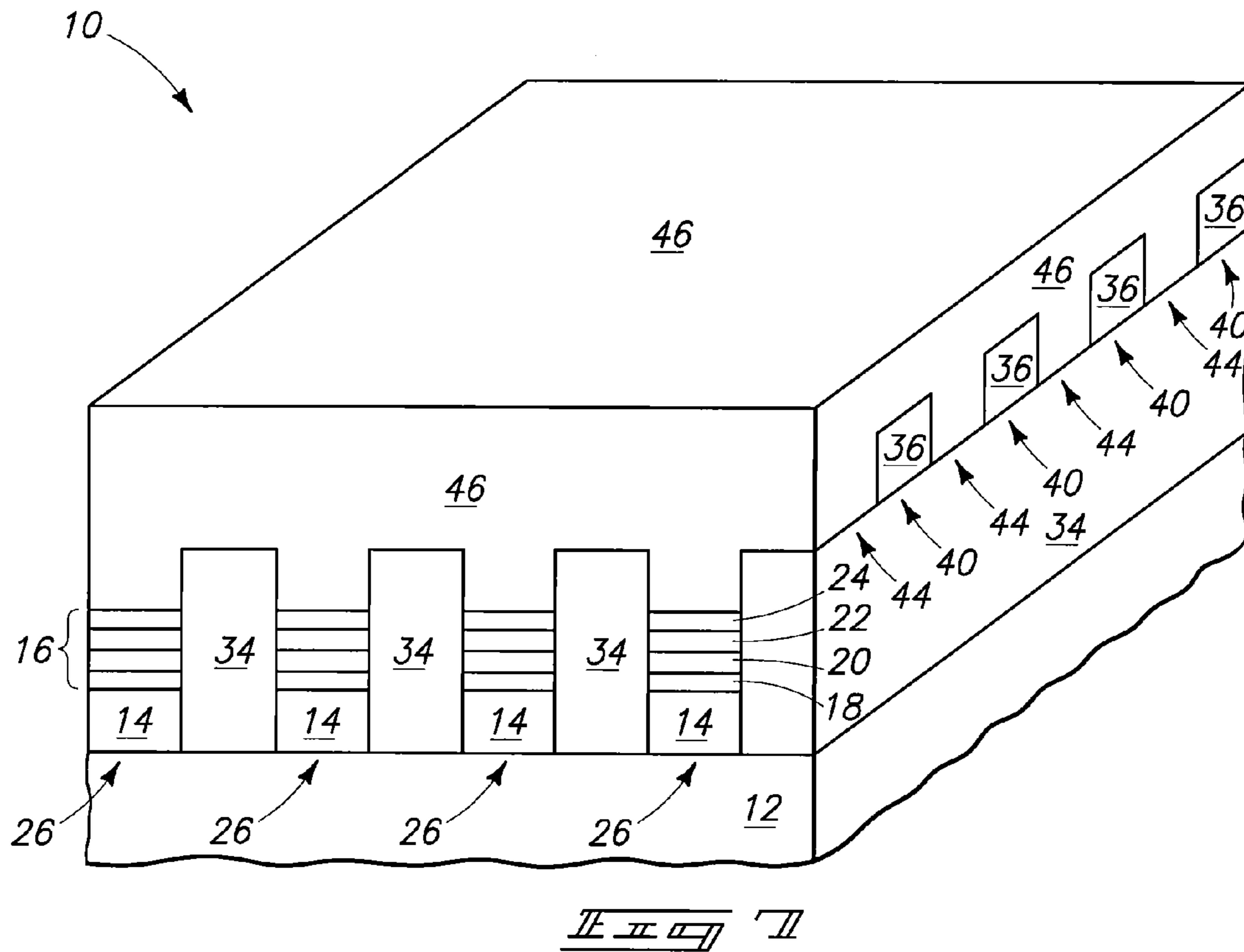
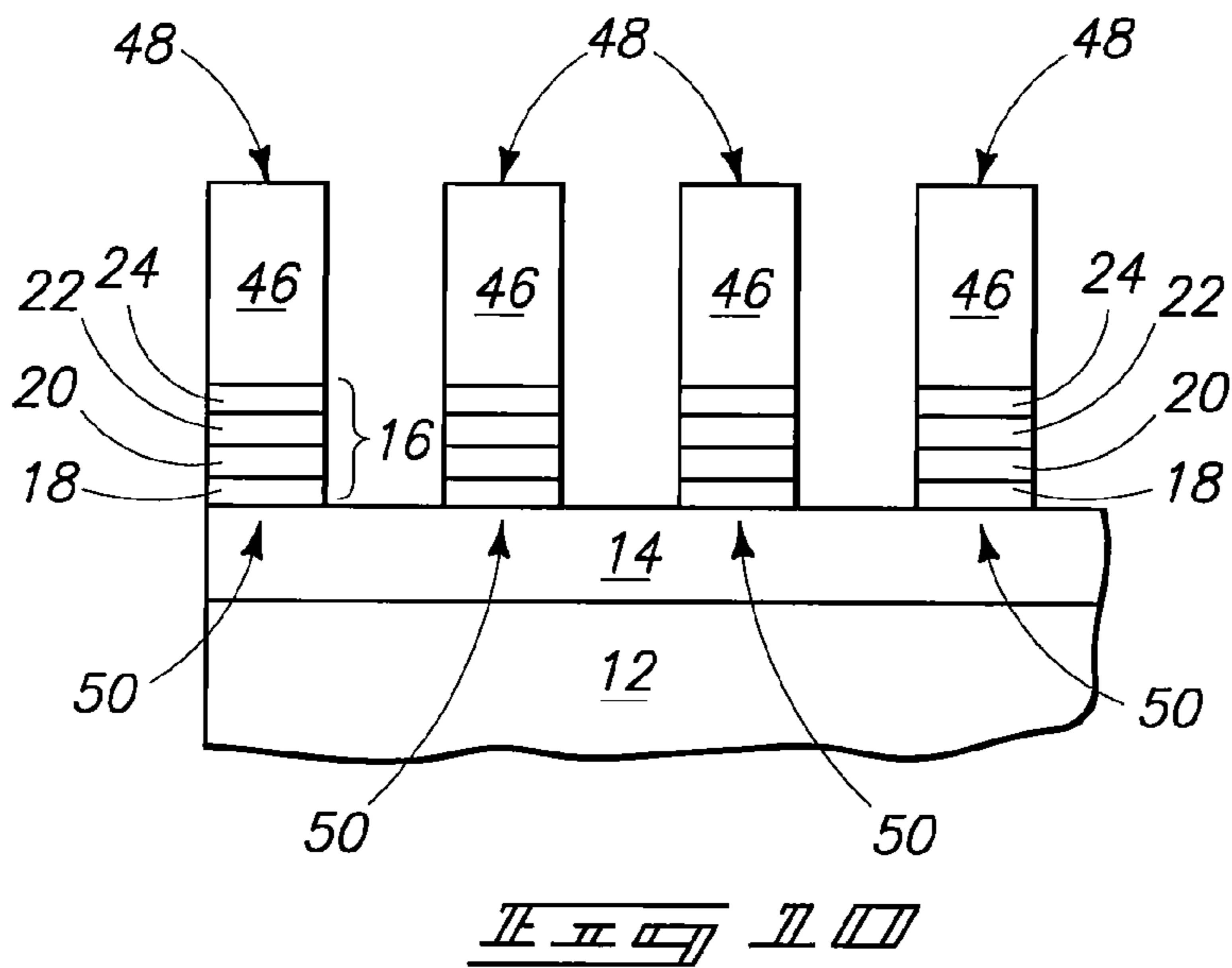
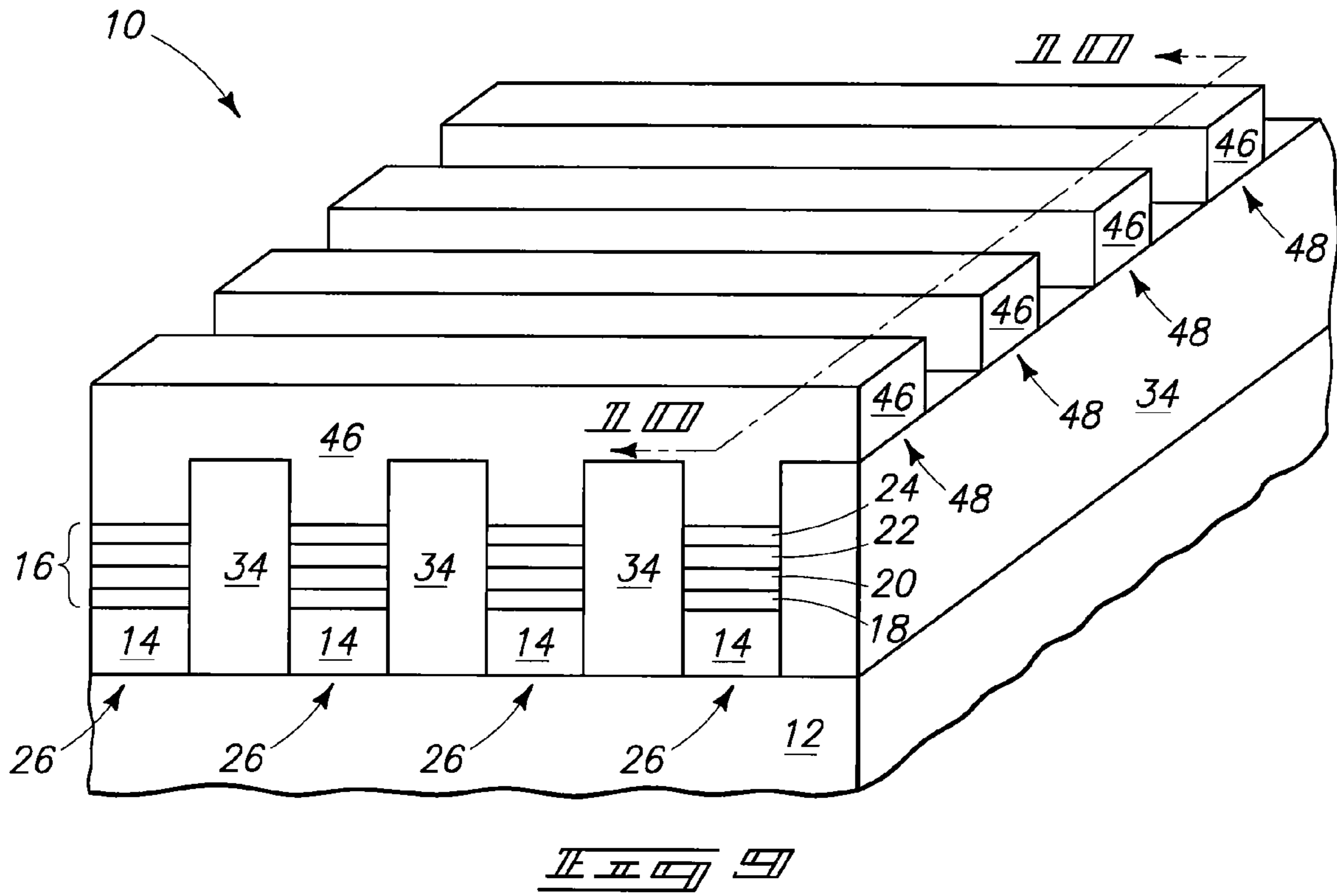


FIG. 3





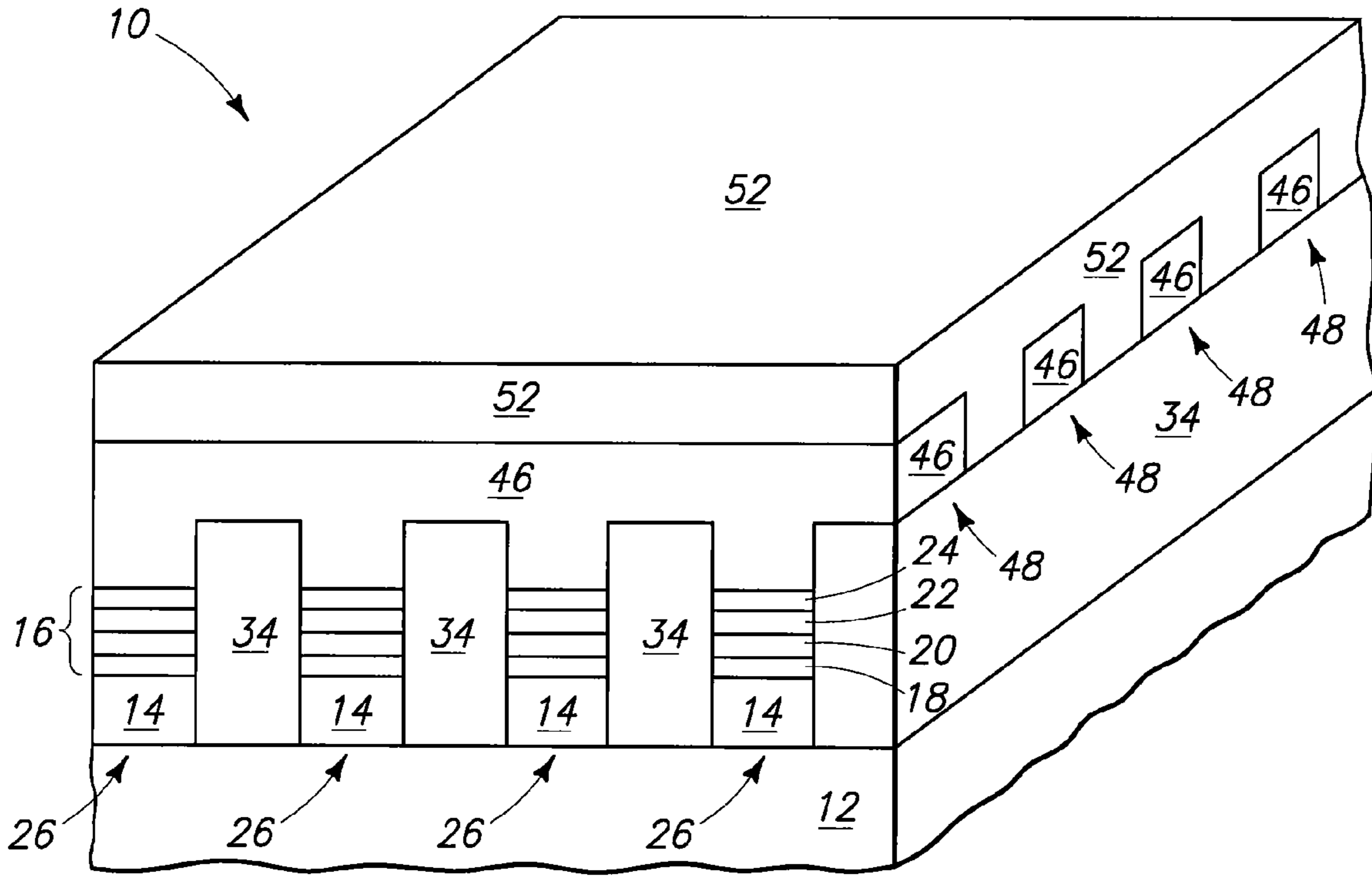


FIG. 5

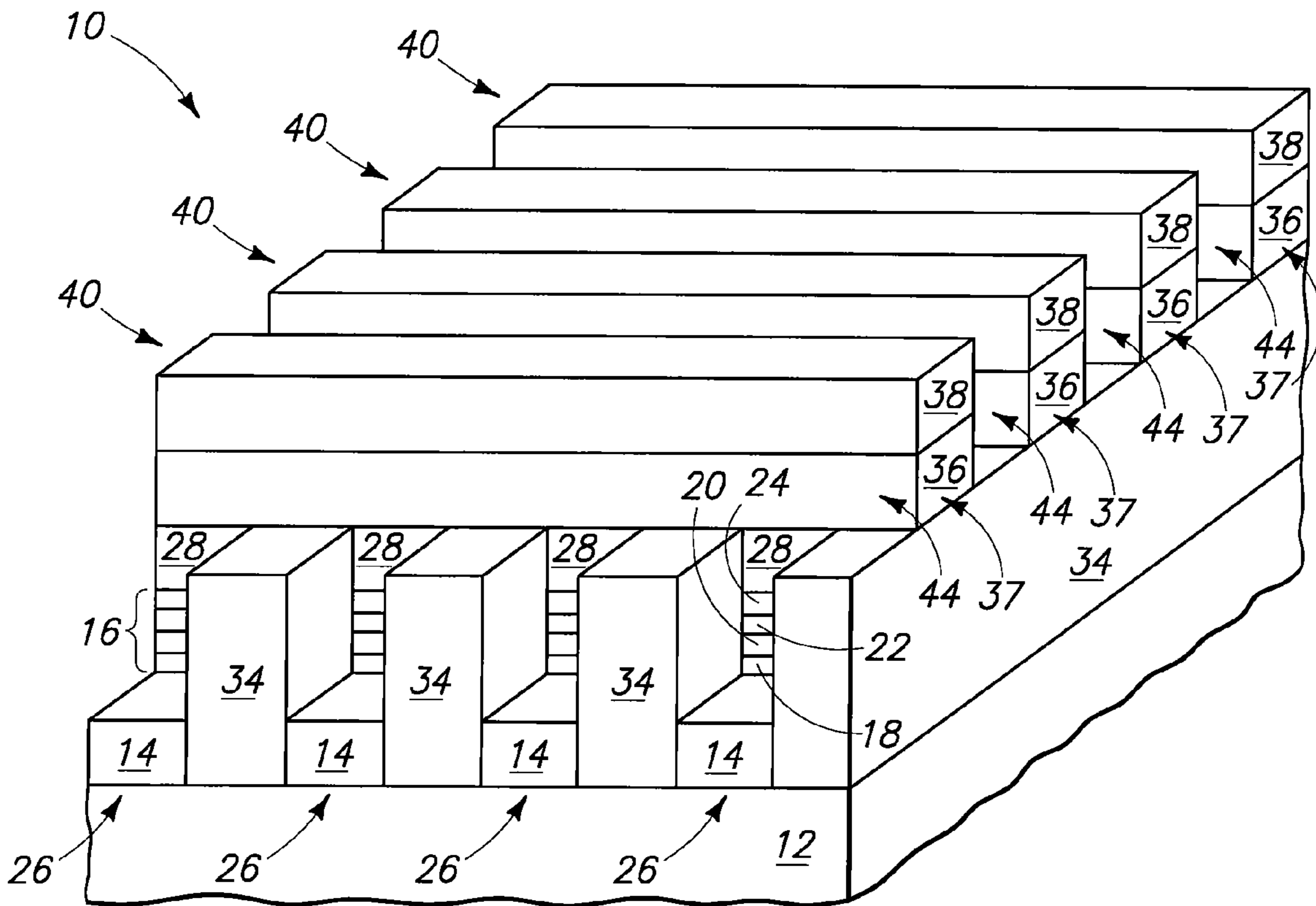
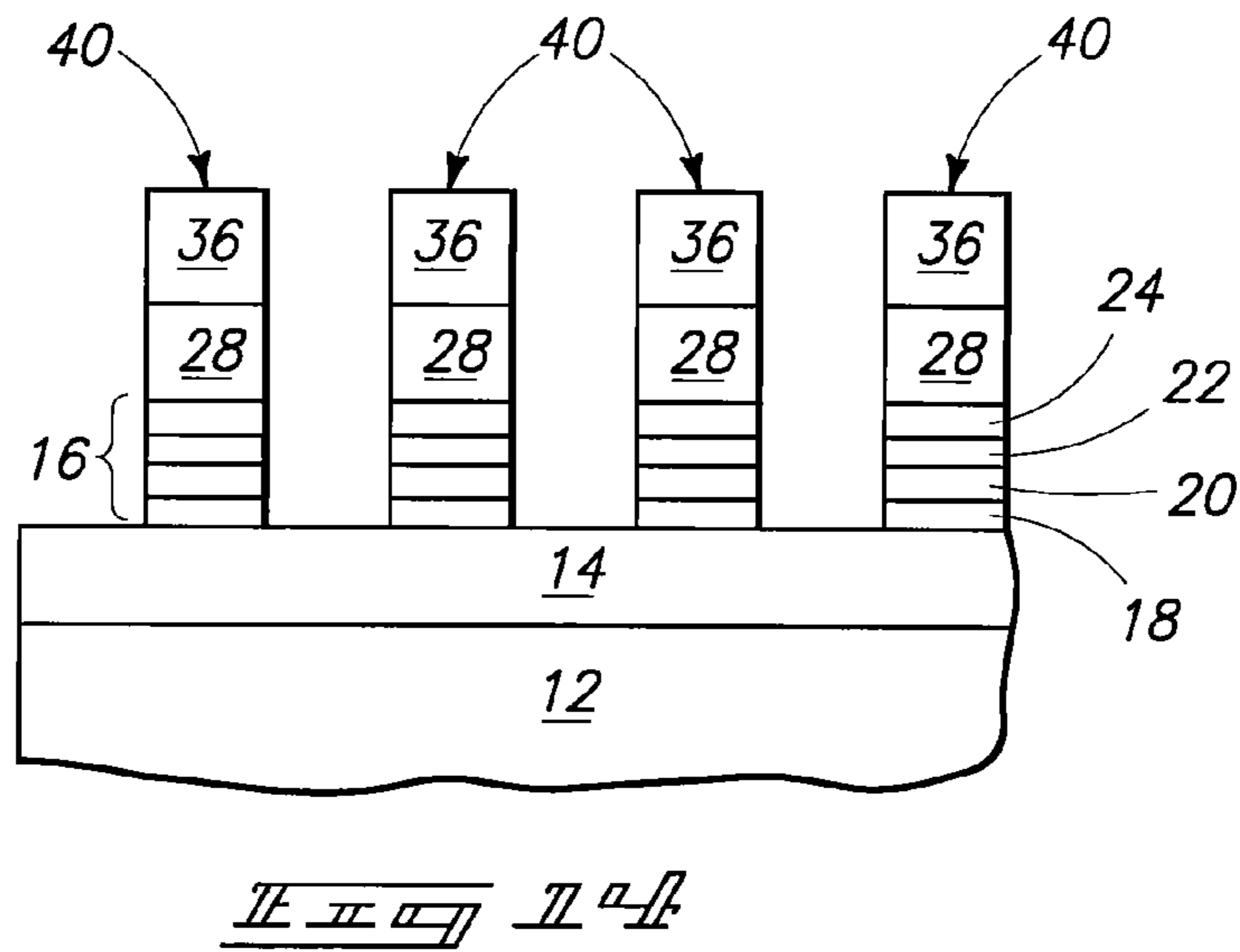
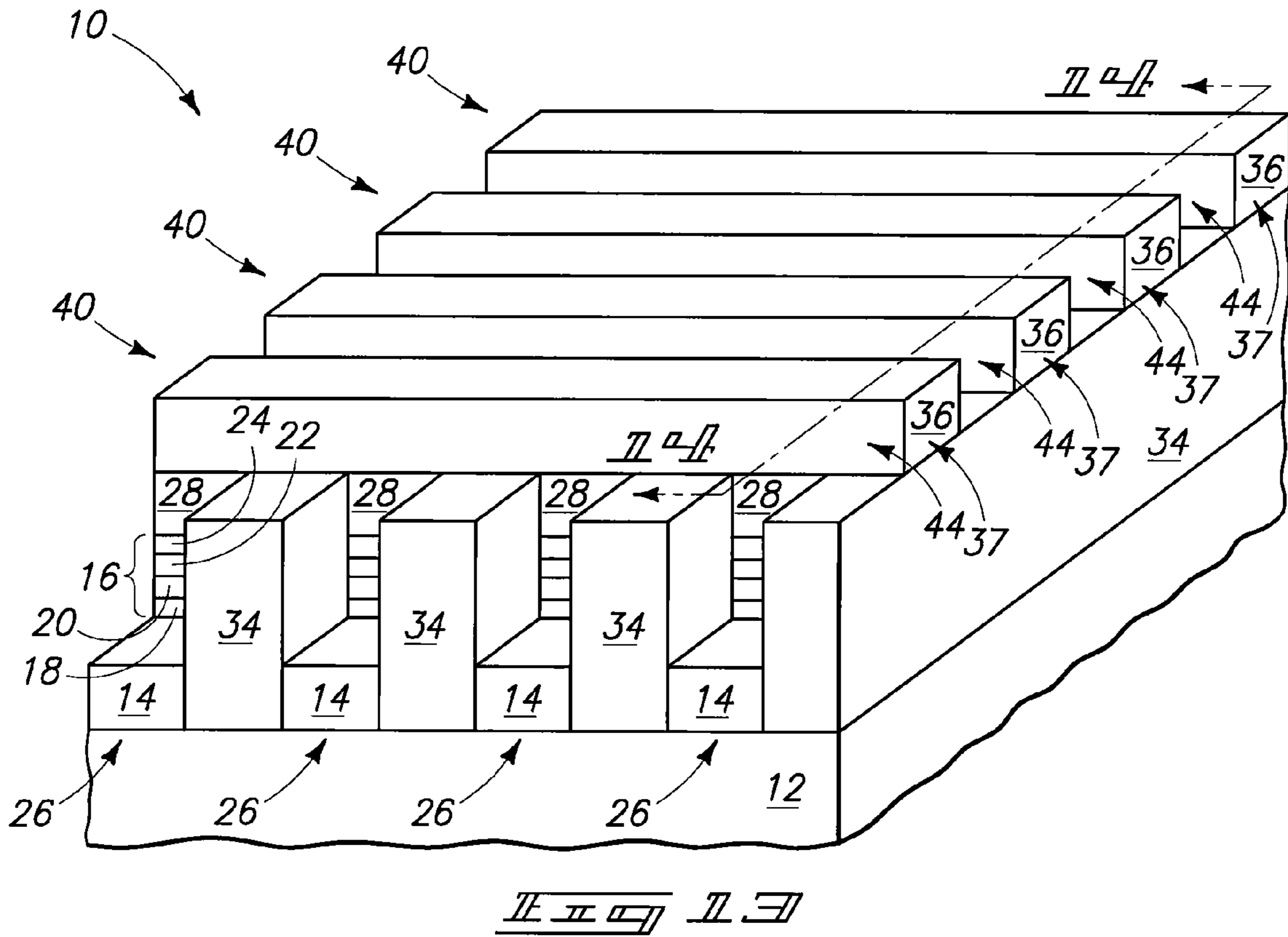
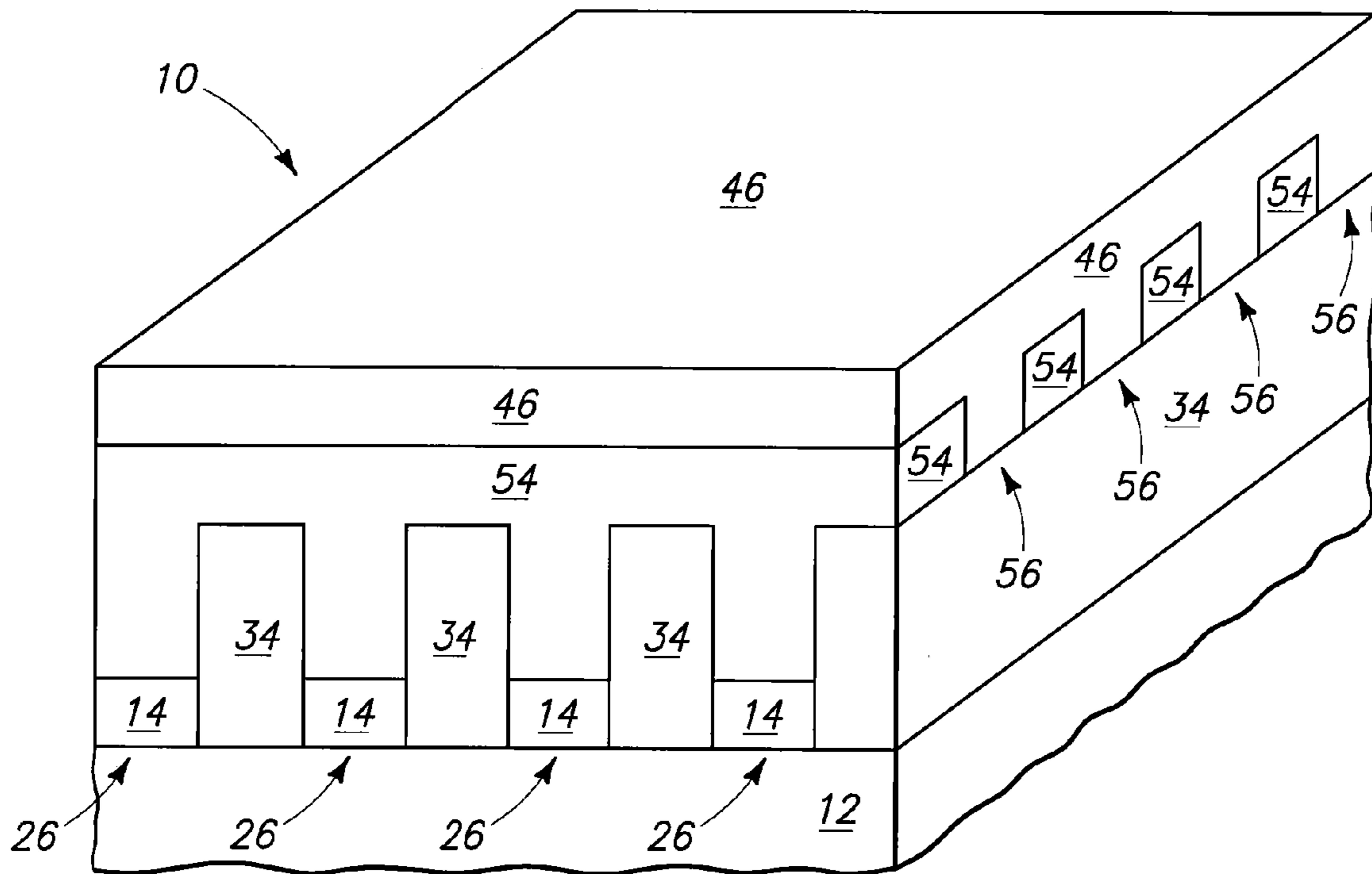
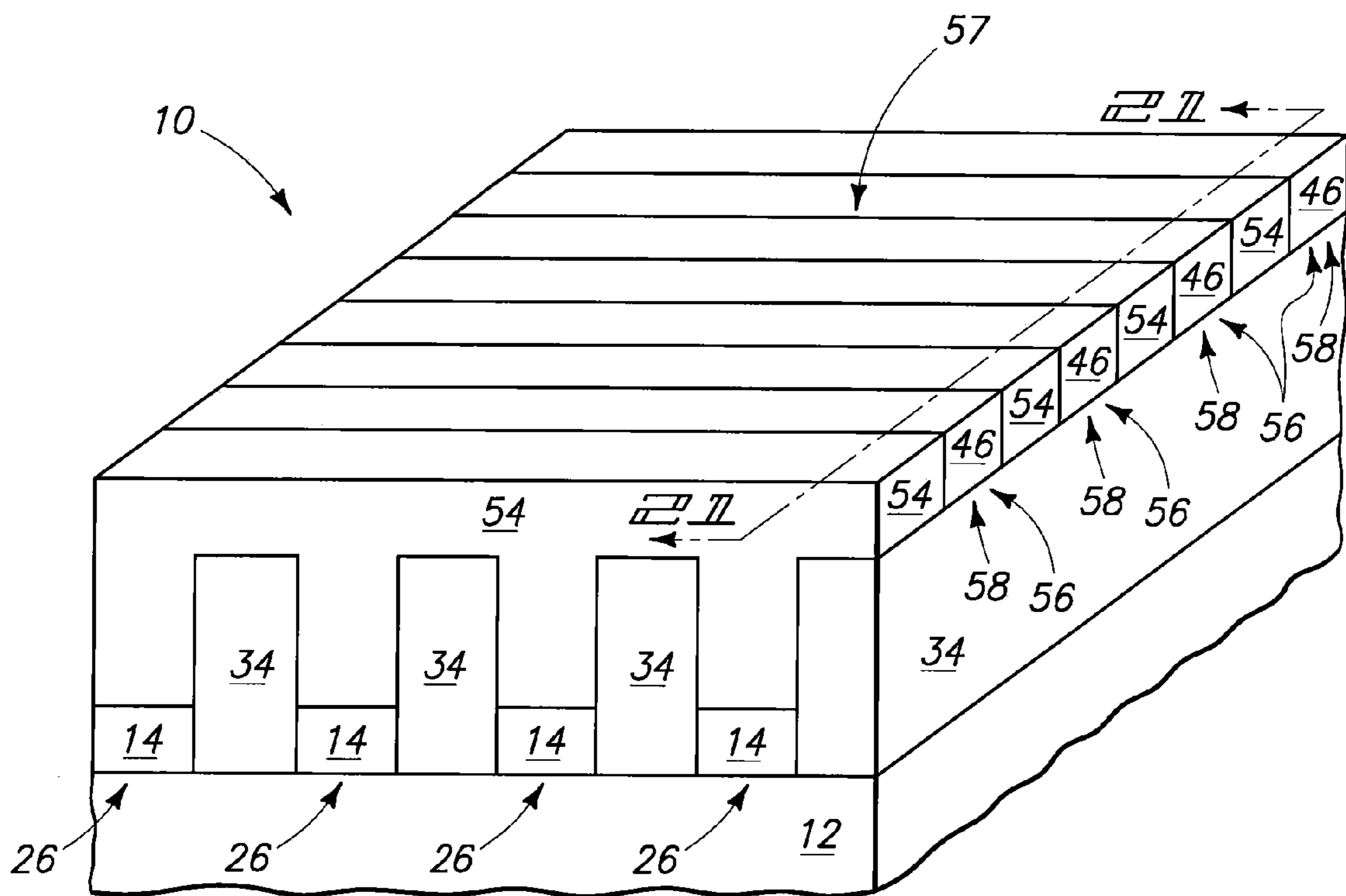


FIG. 6





I-I II-II



I-I II-II

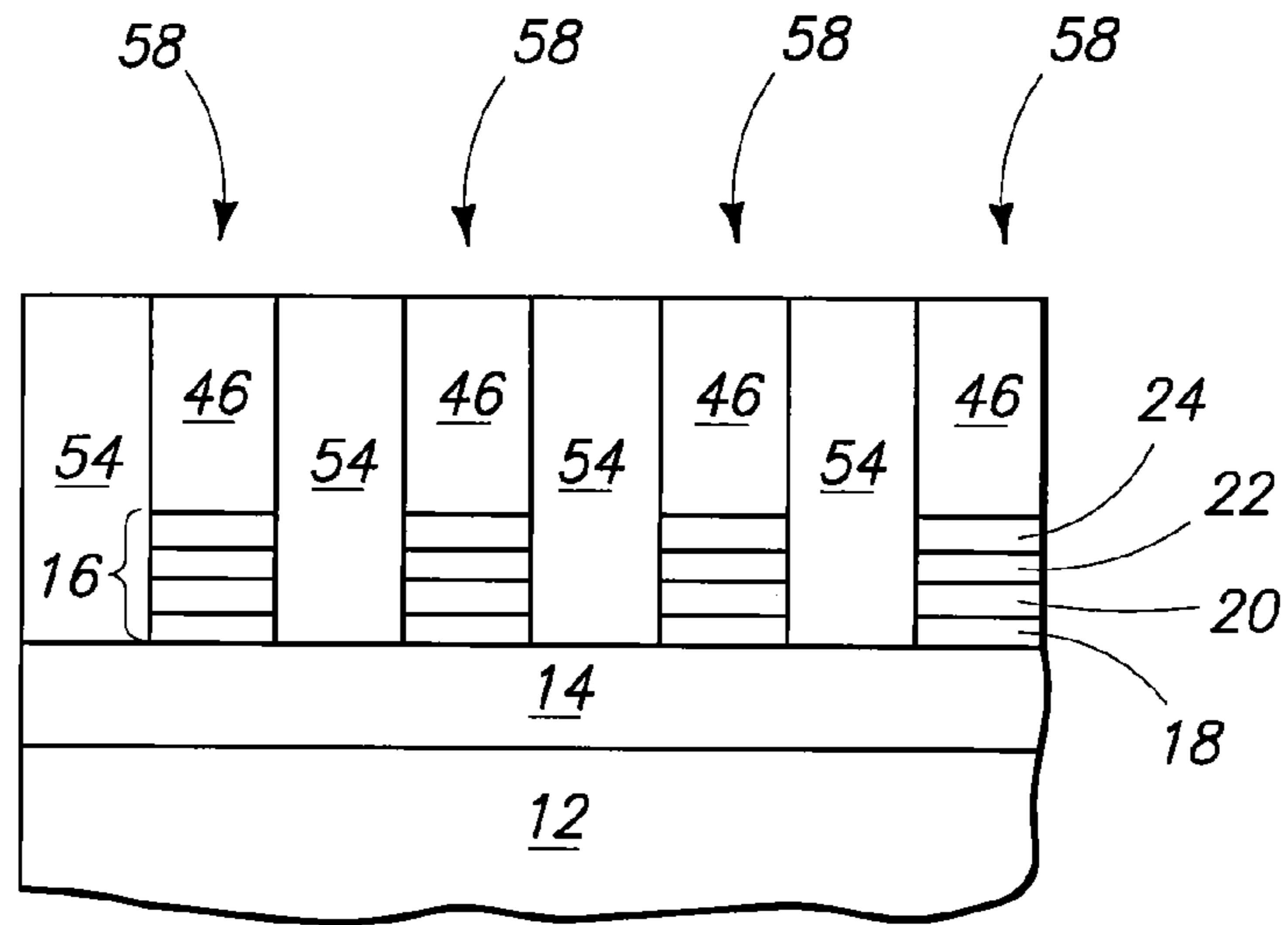


FIG. 21

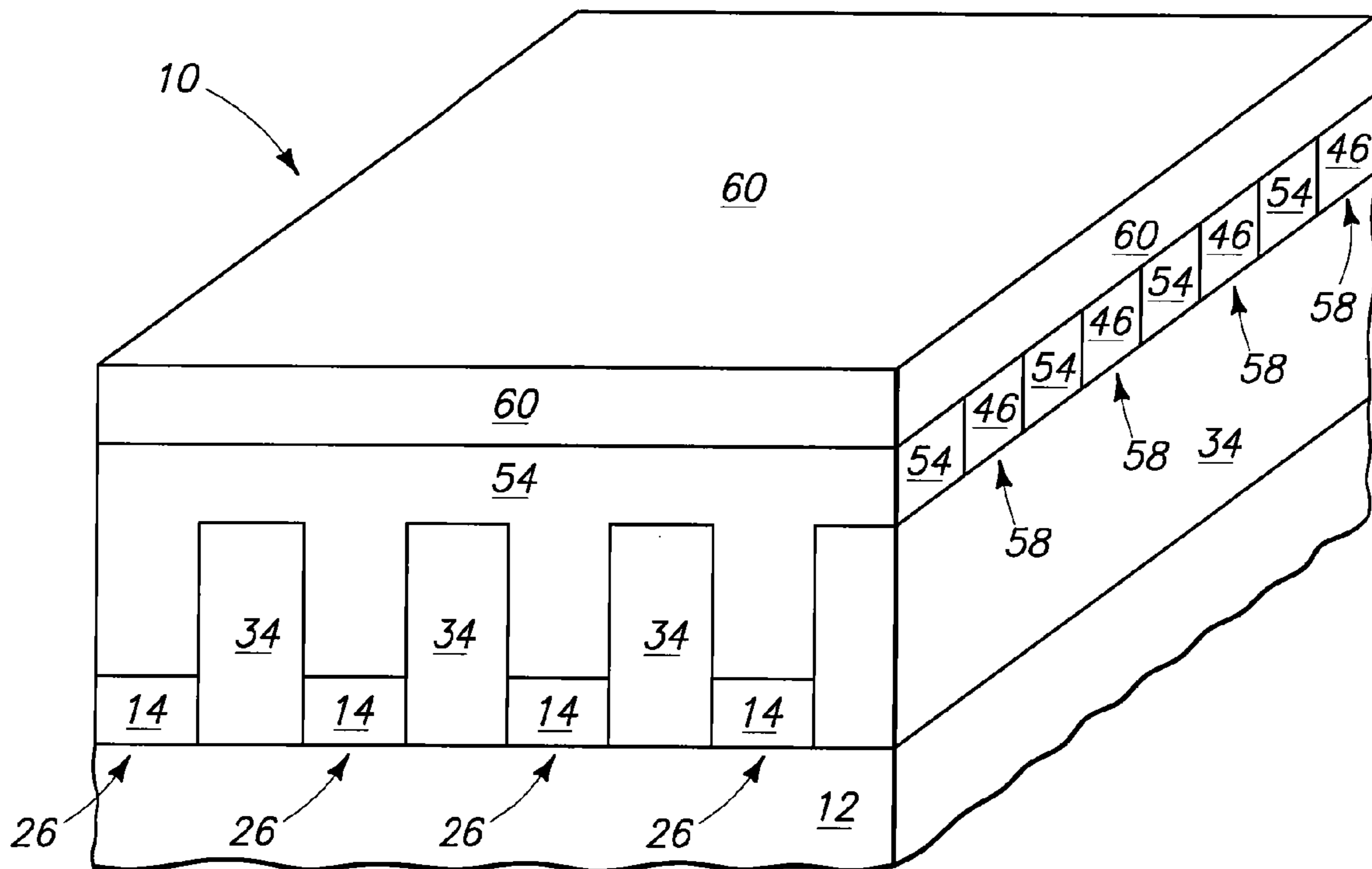
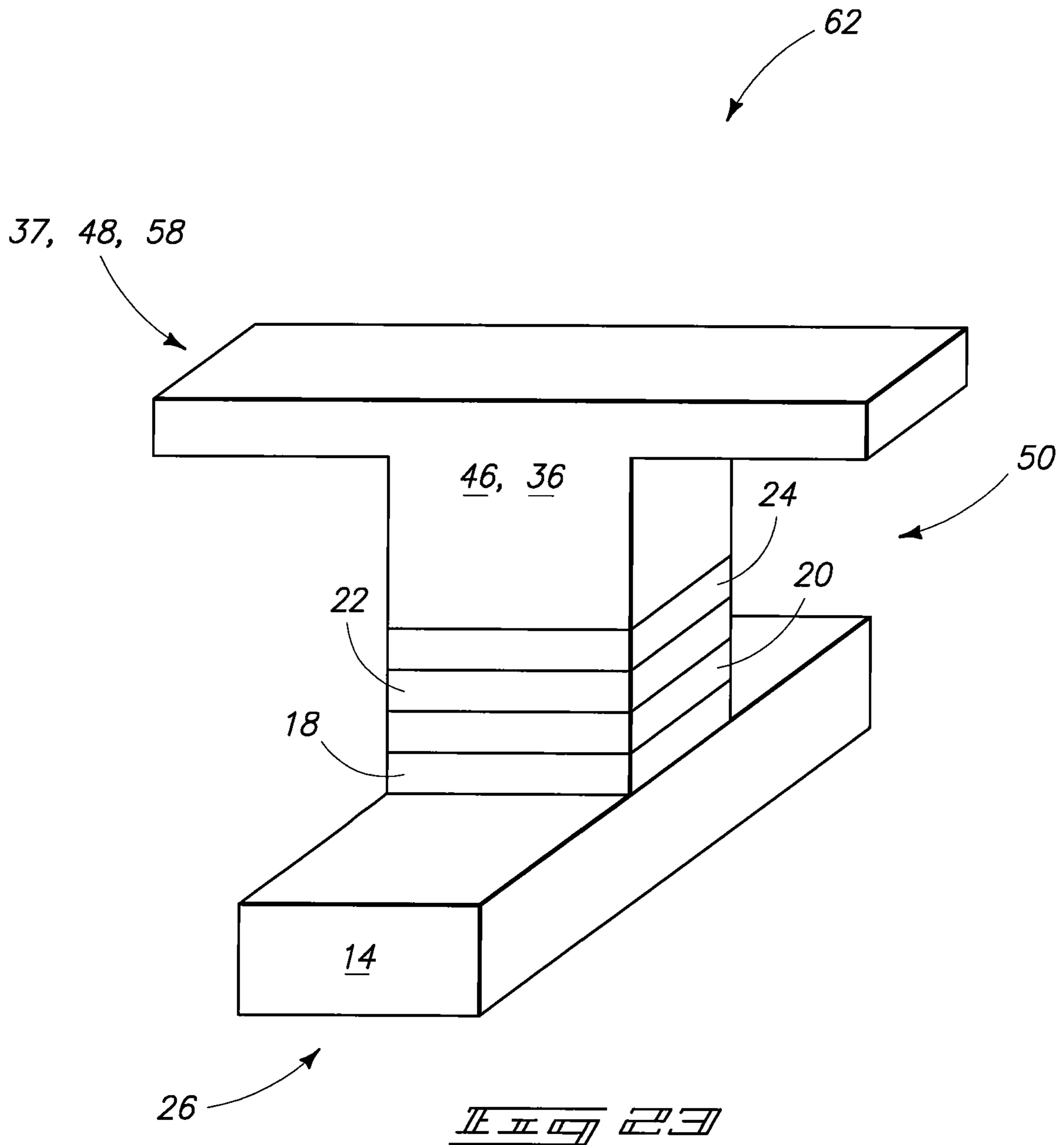
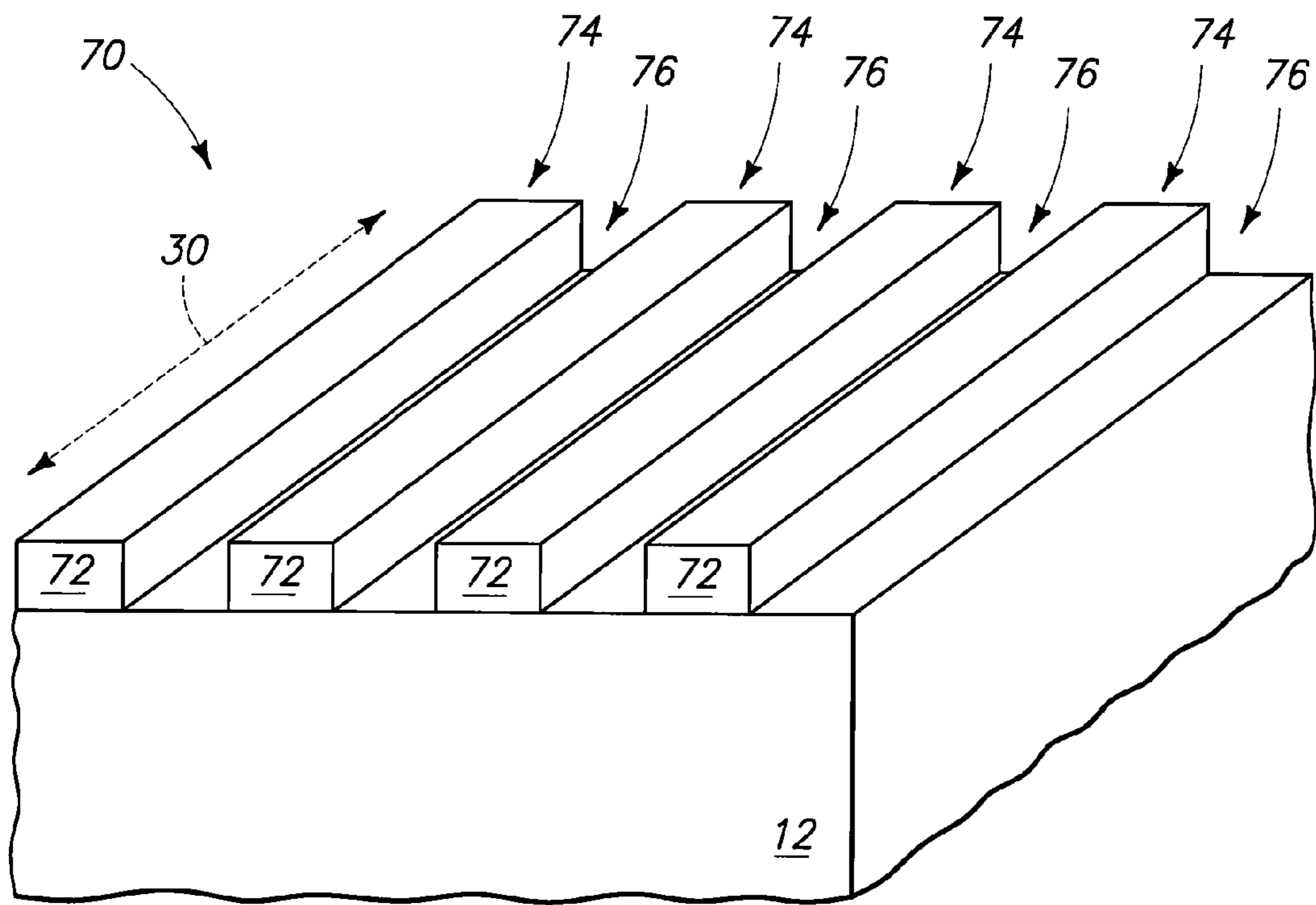
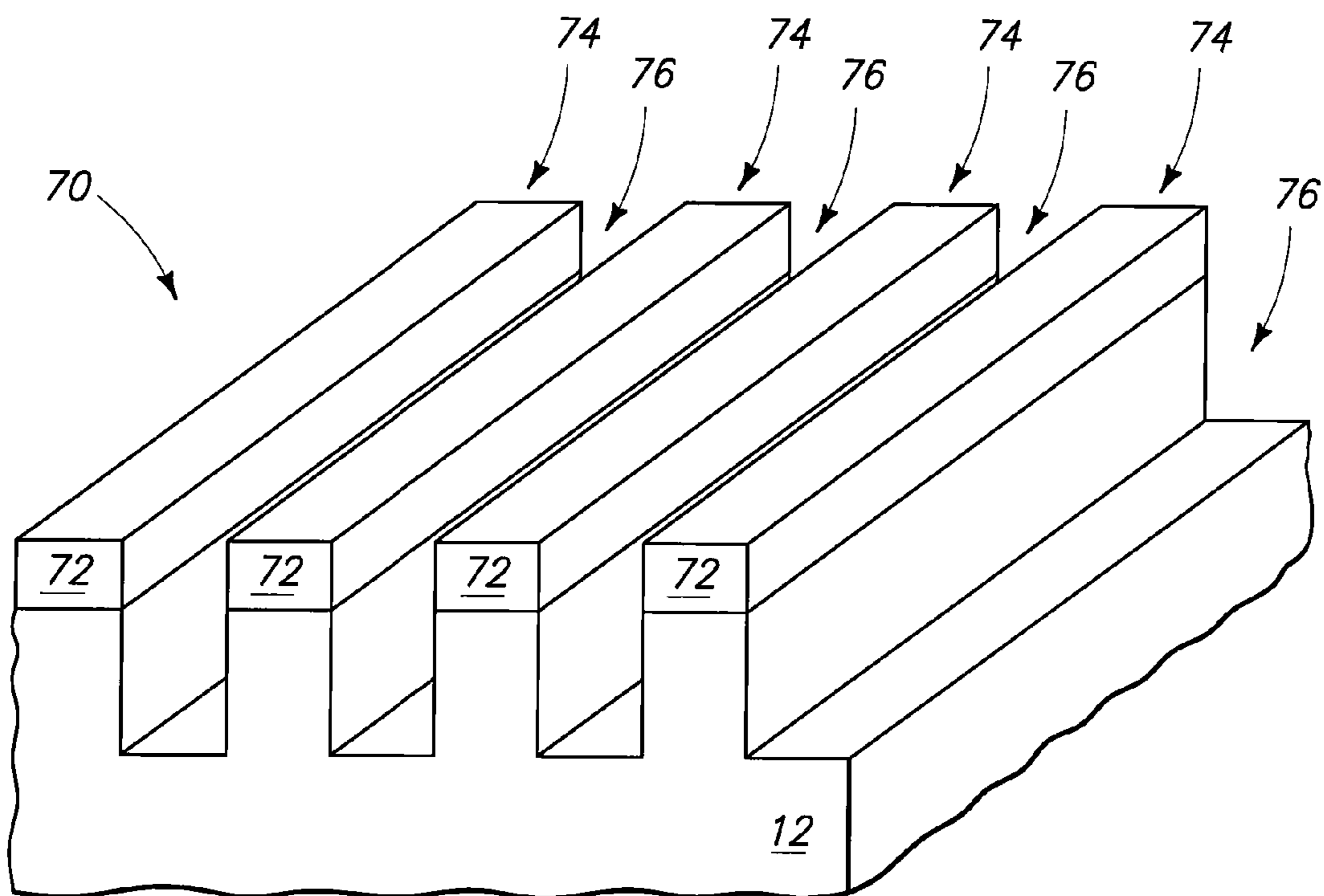


FIG. 22





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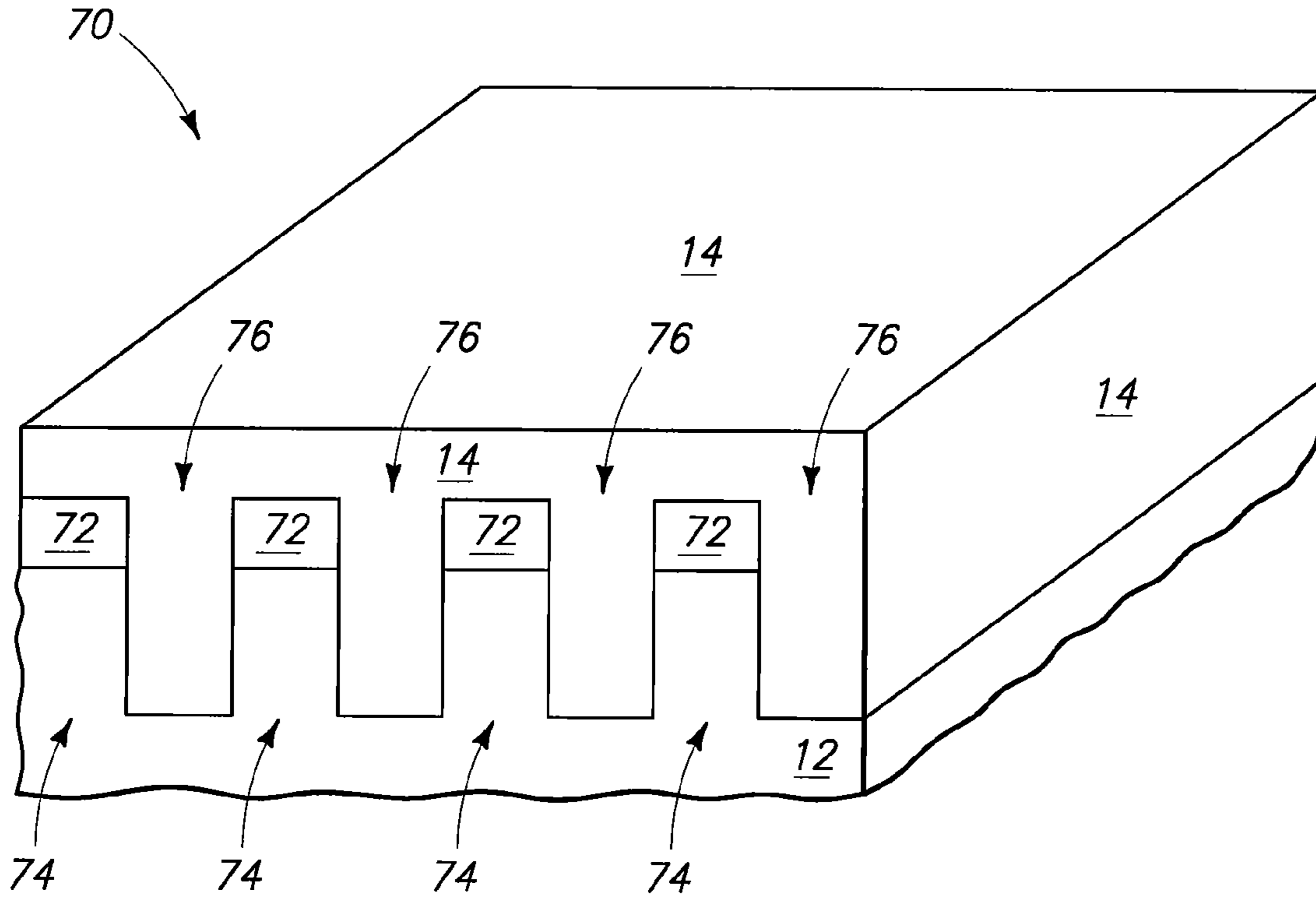


FIG. 26

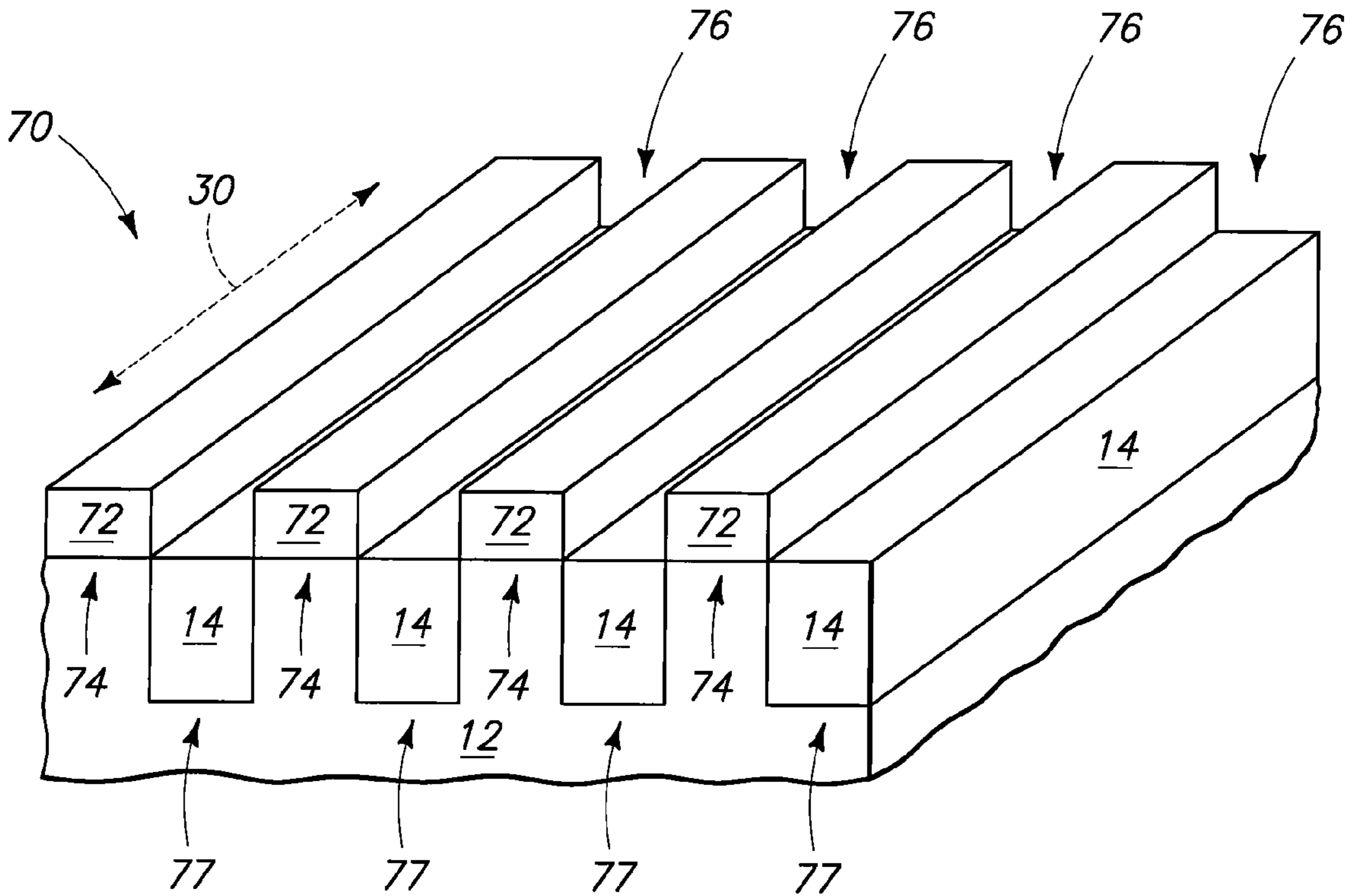


FIG. 27

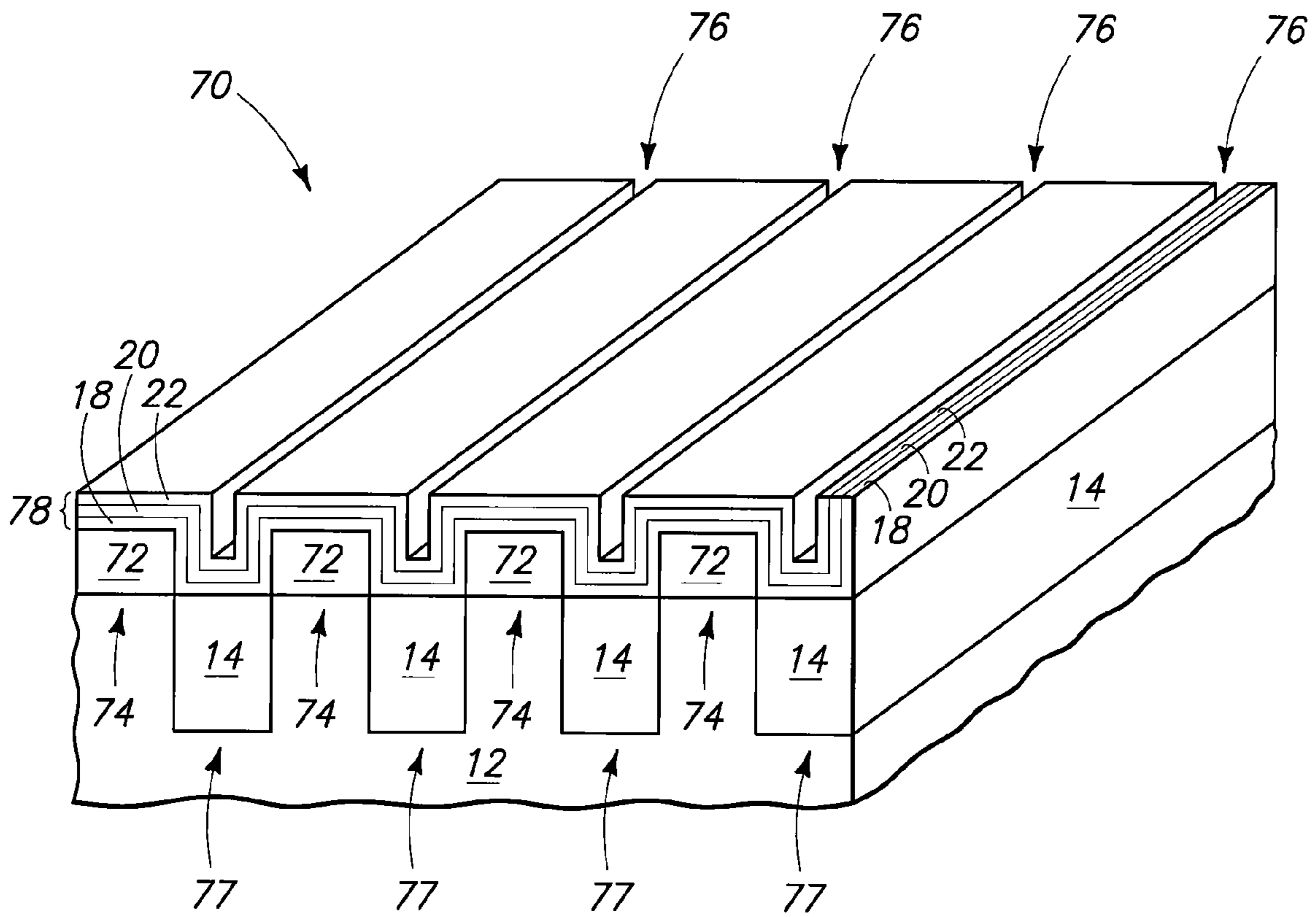


FIG. 28

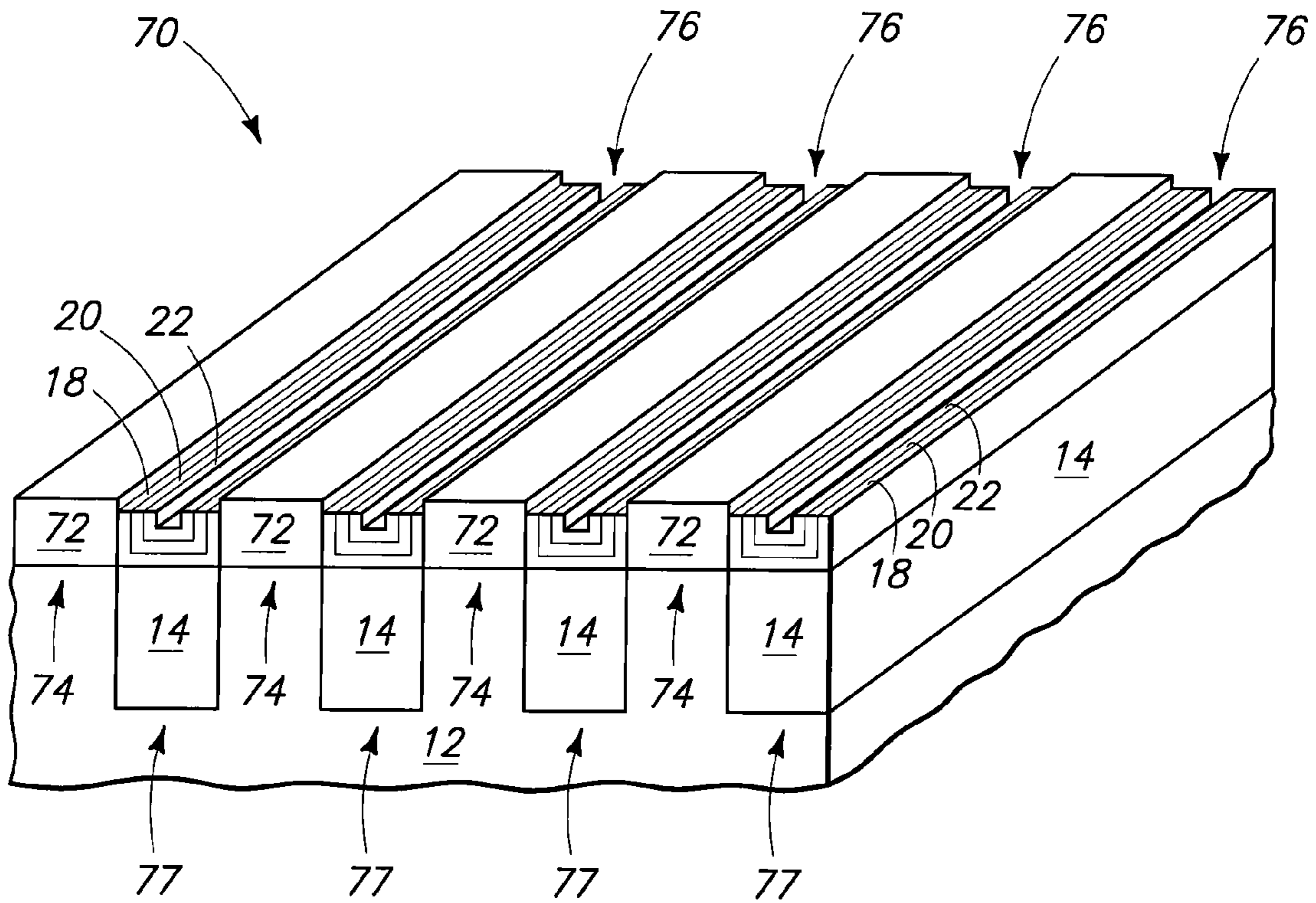
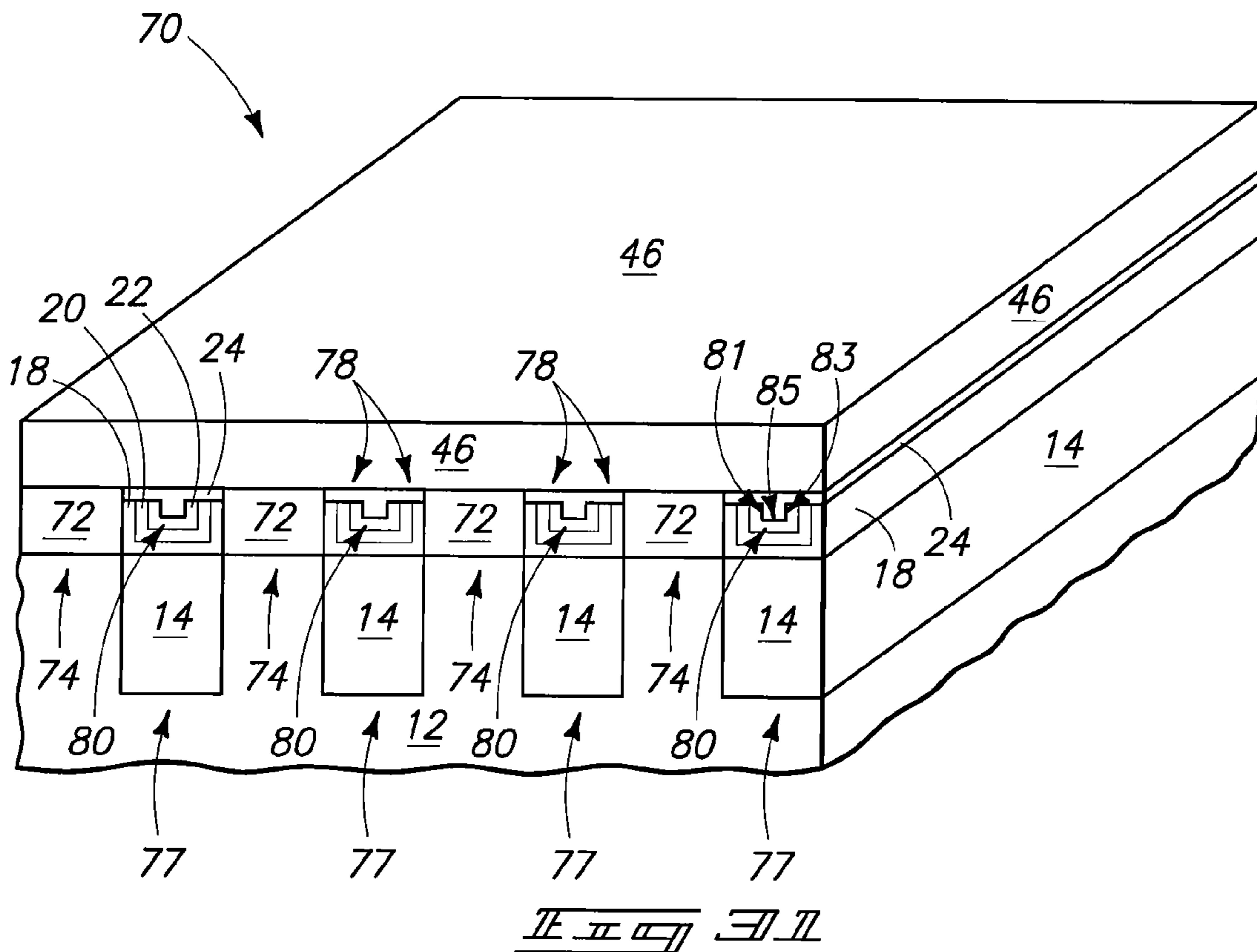
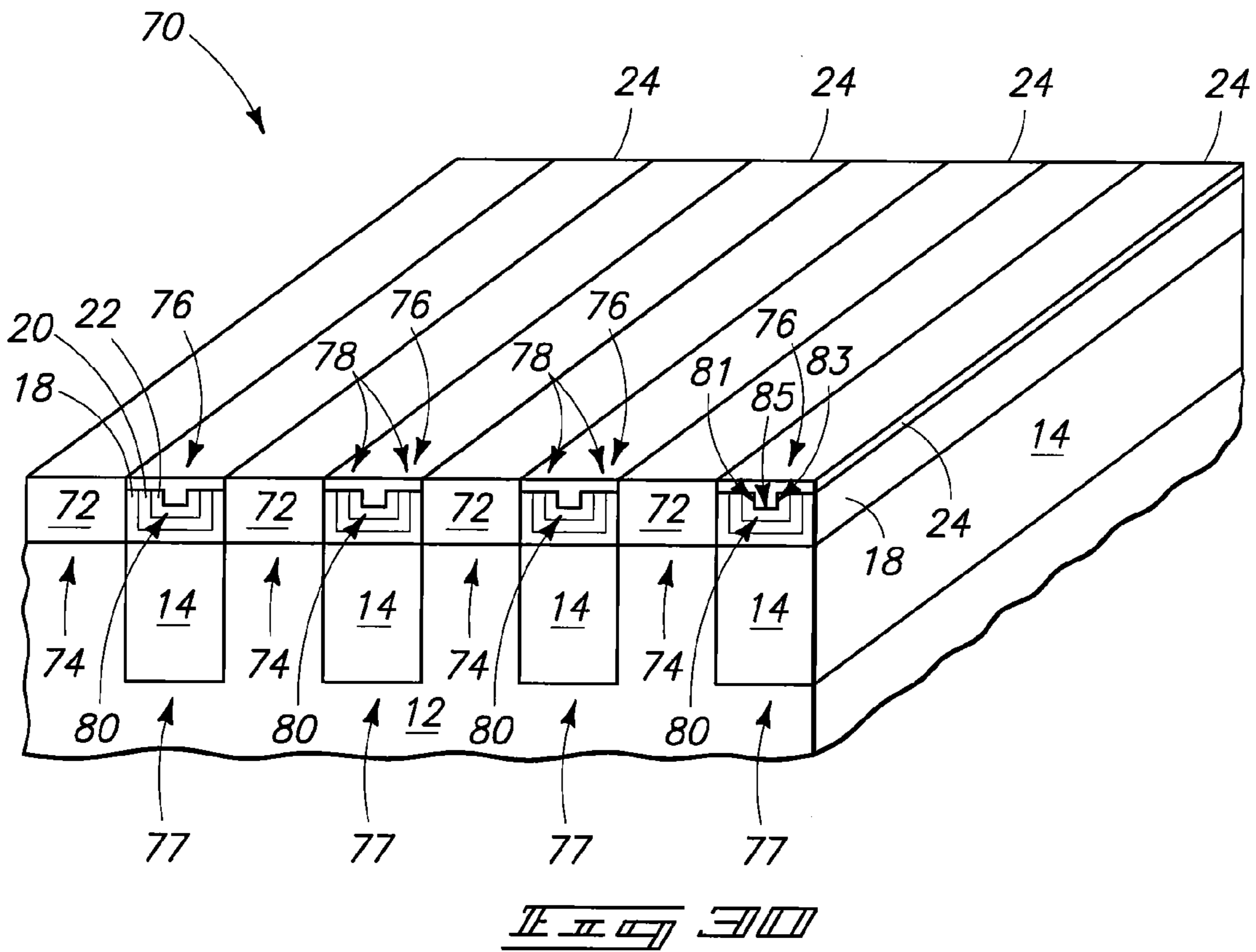
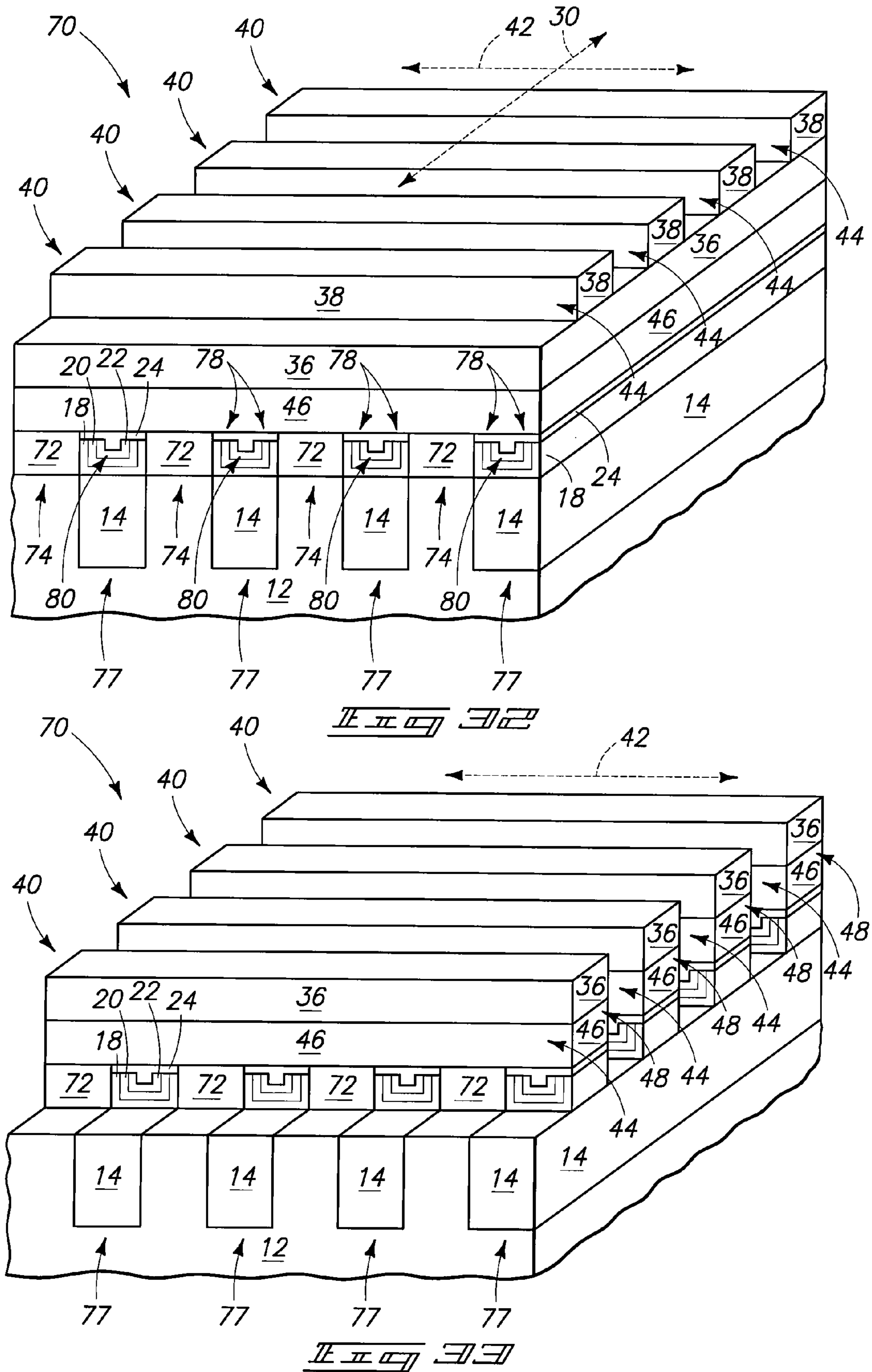
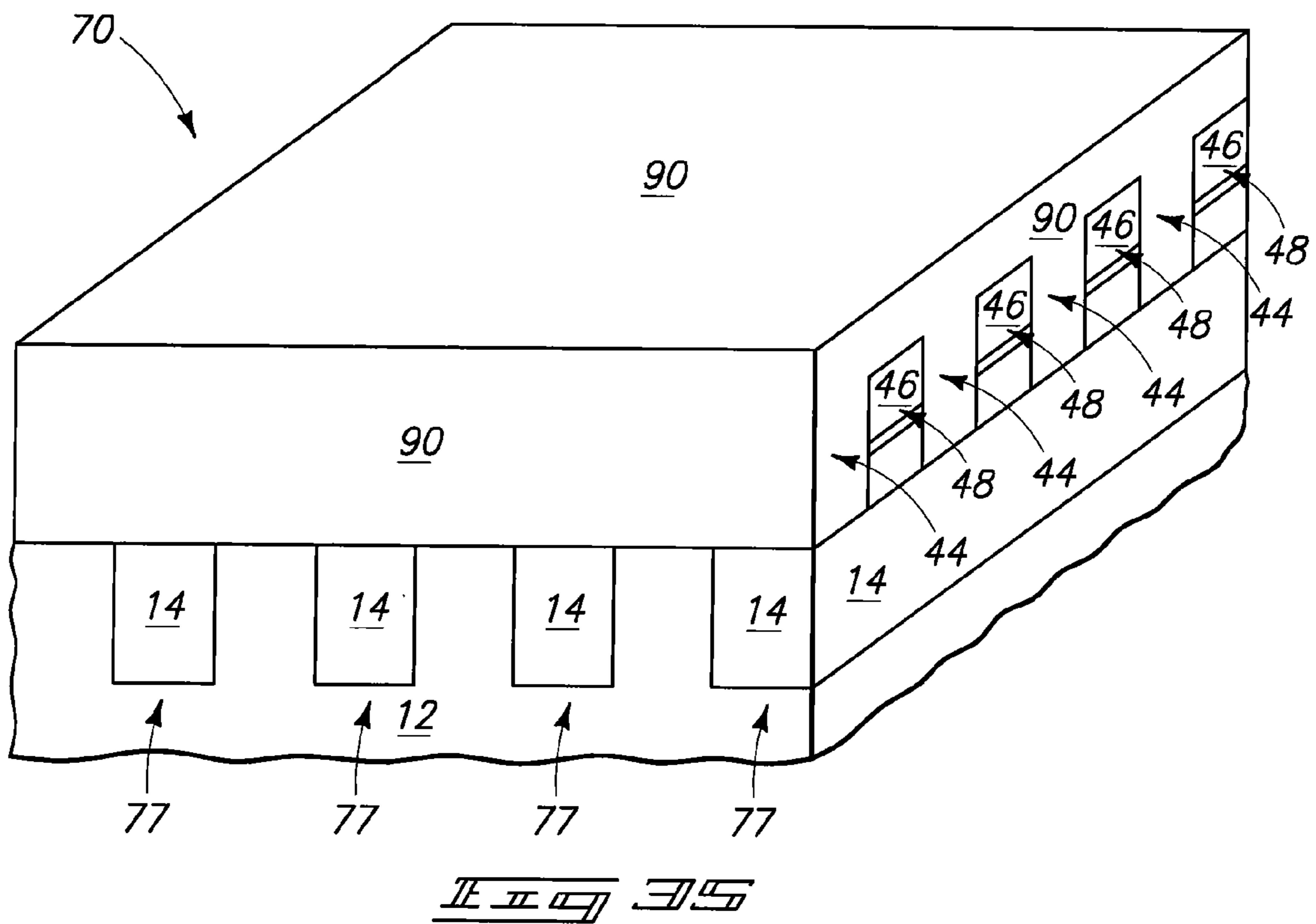
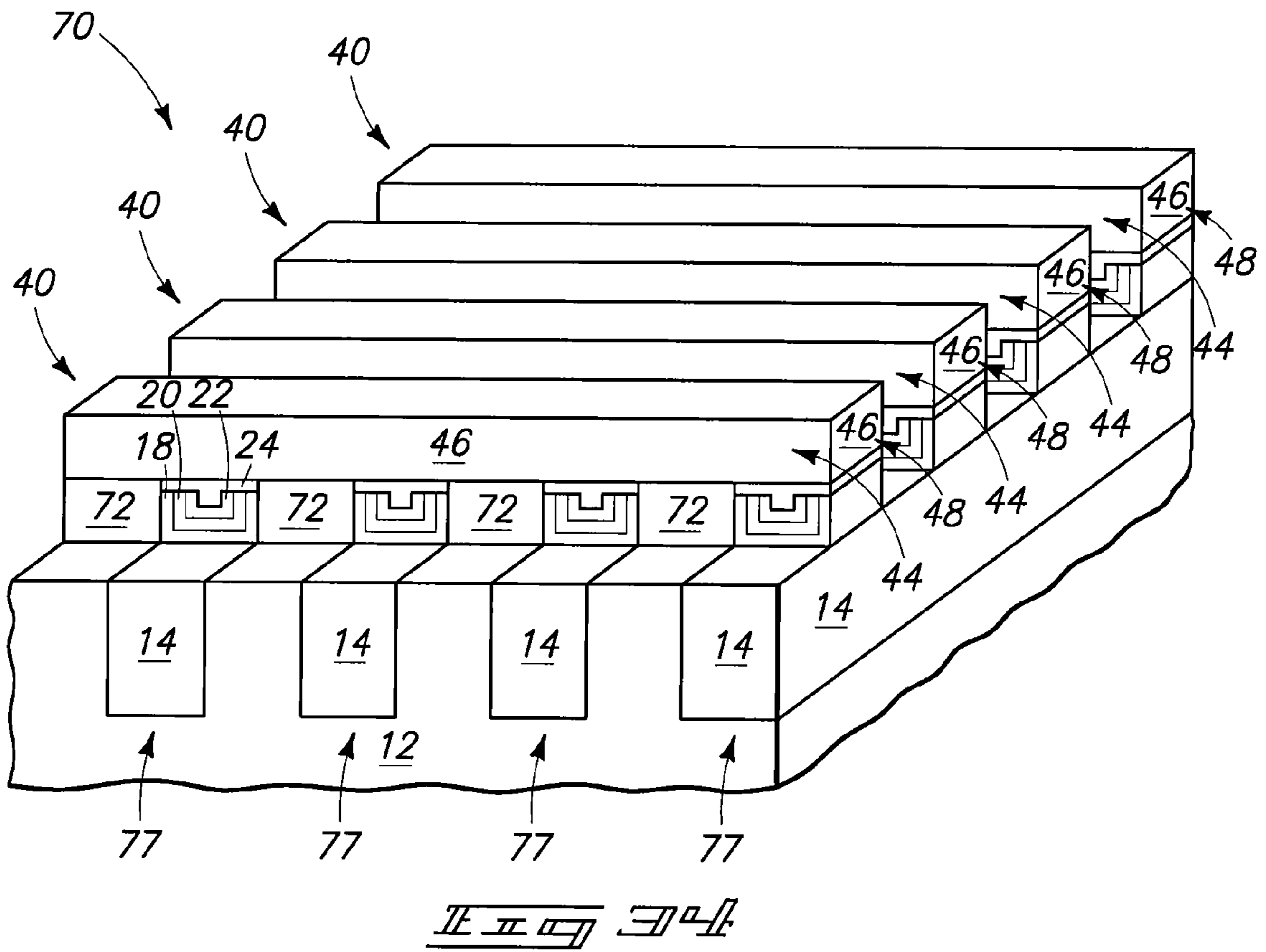
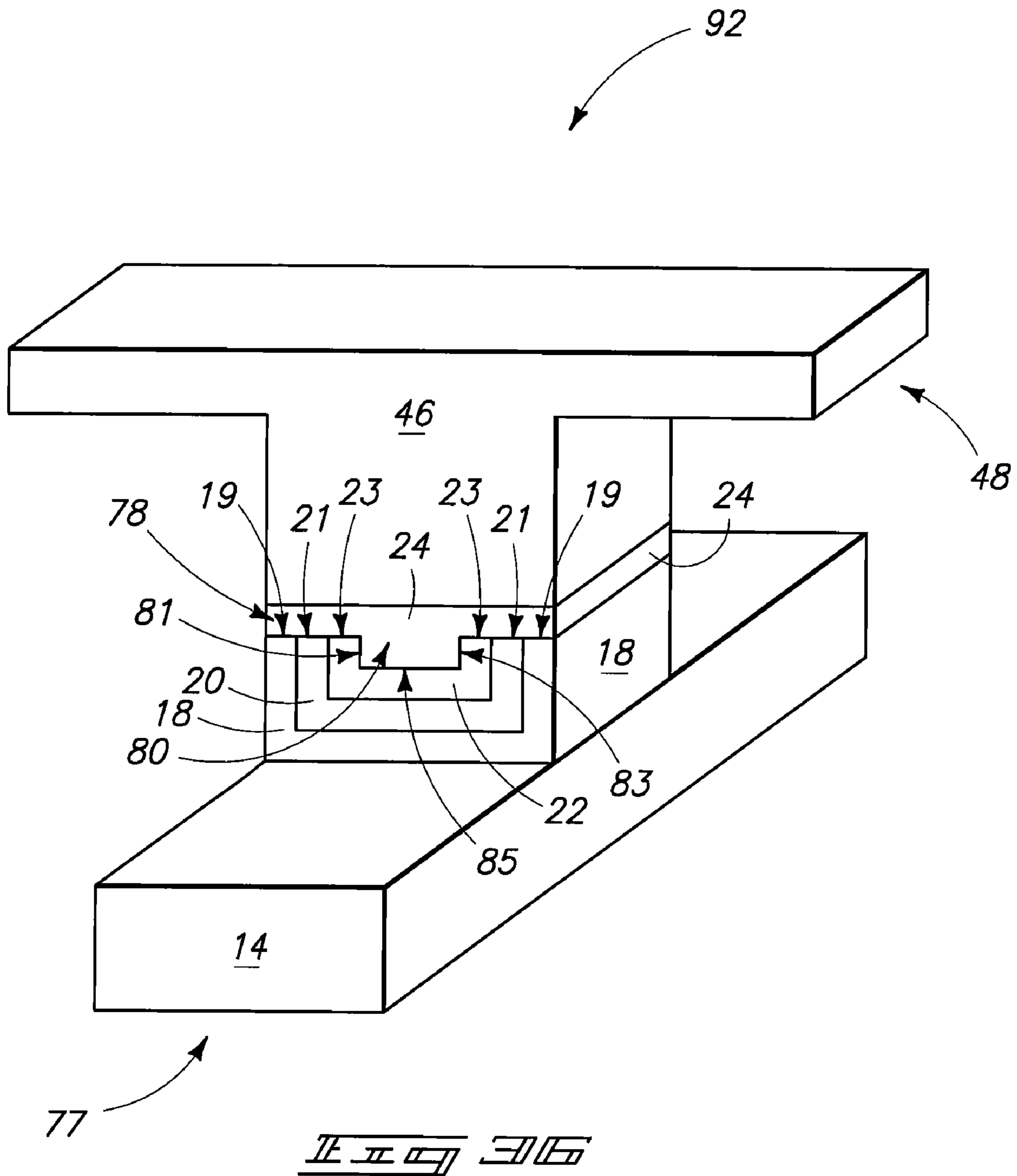


FIG. 29









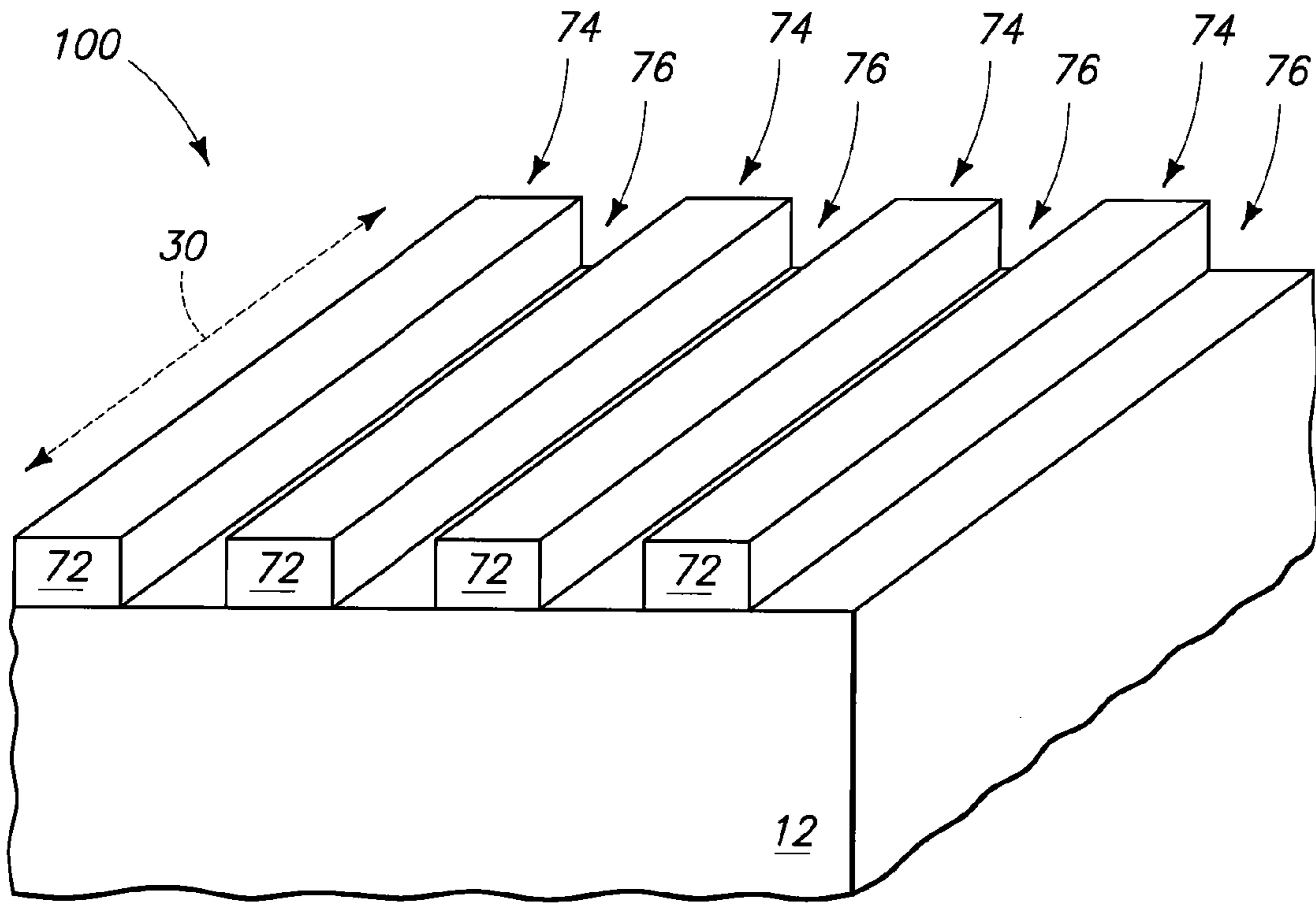


FIG. 3A

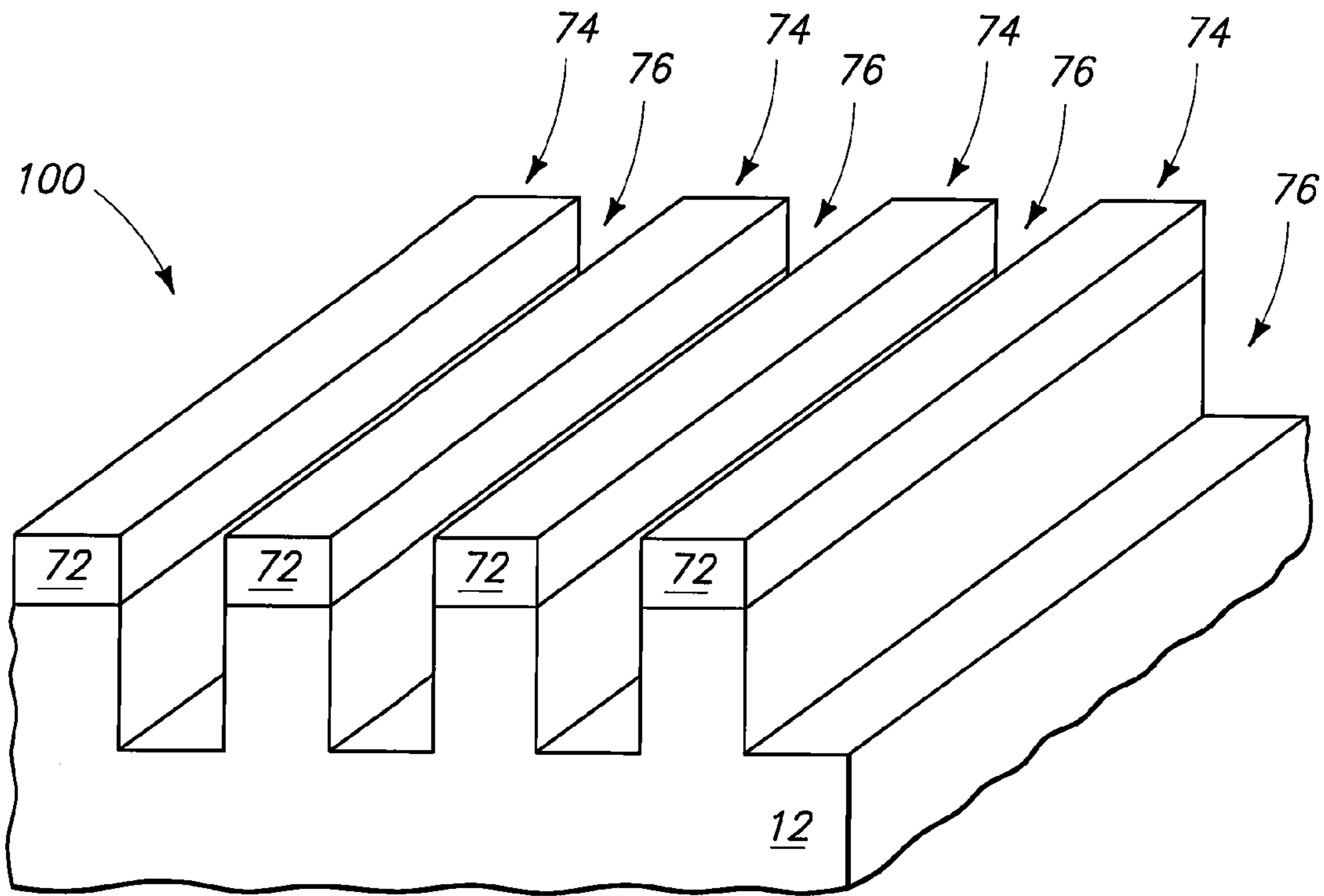
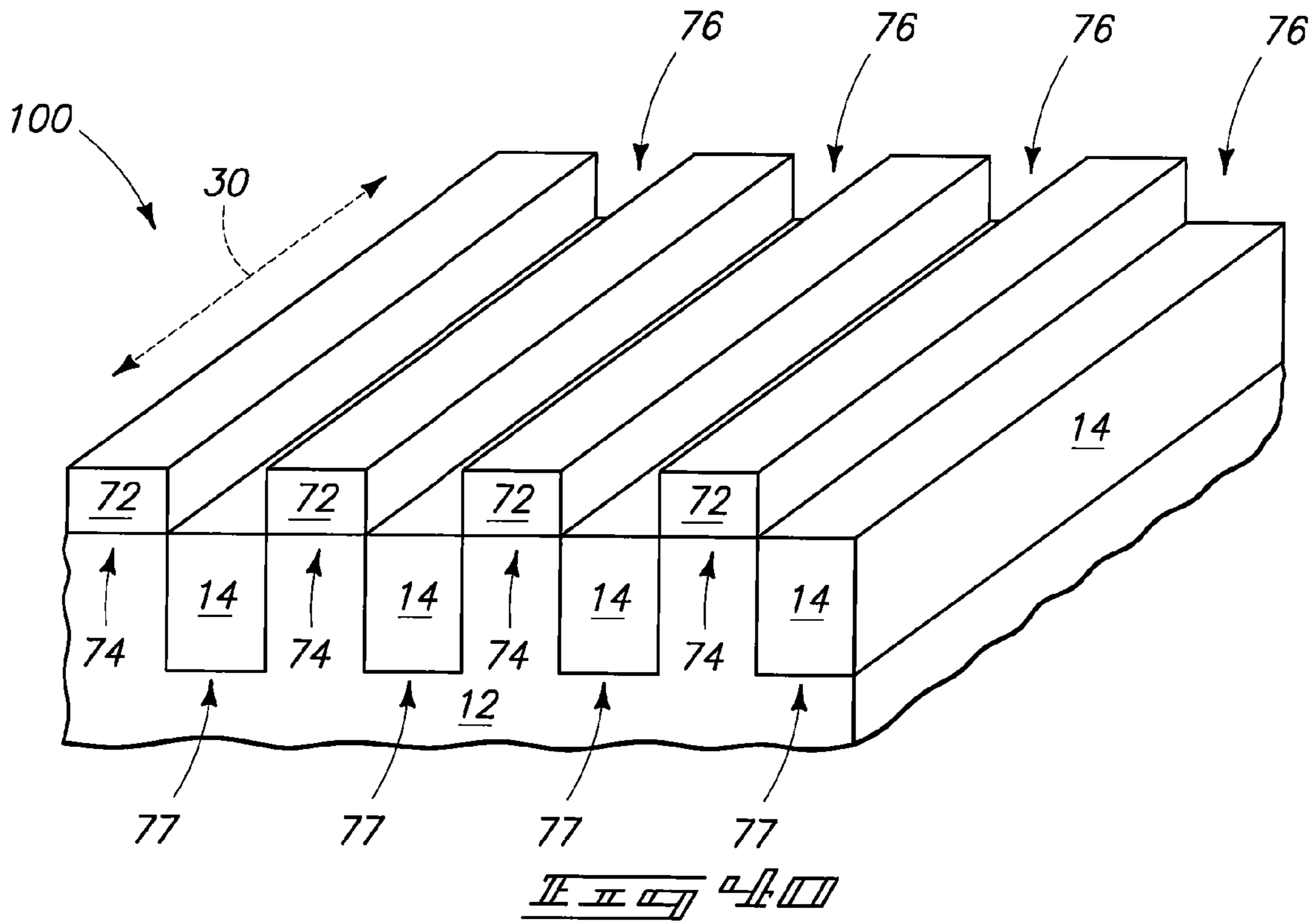
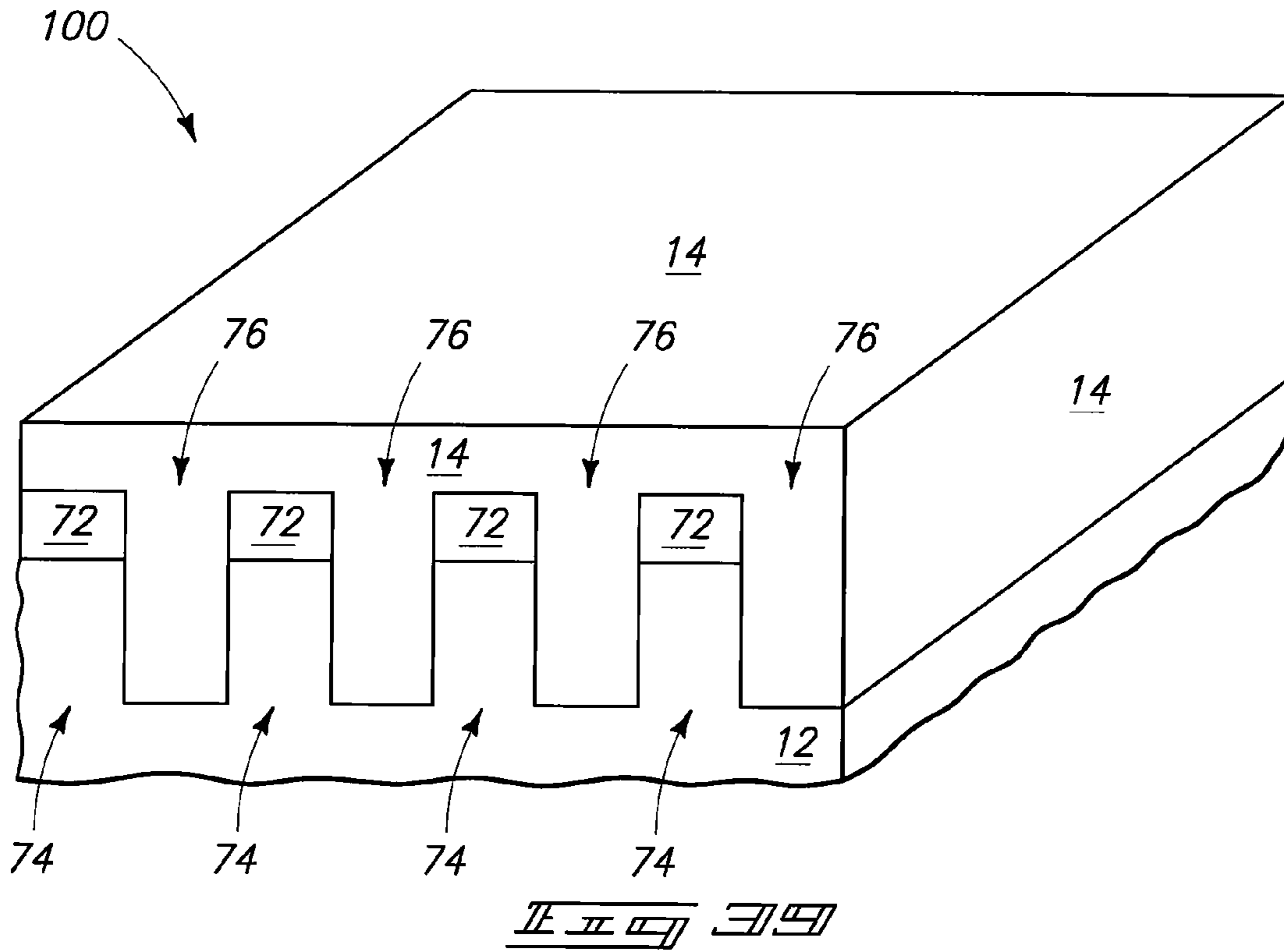
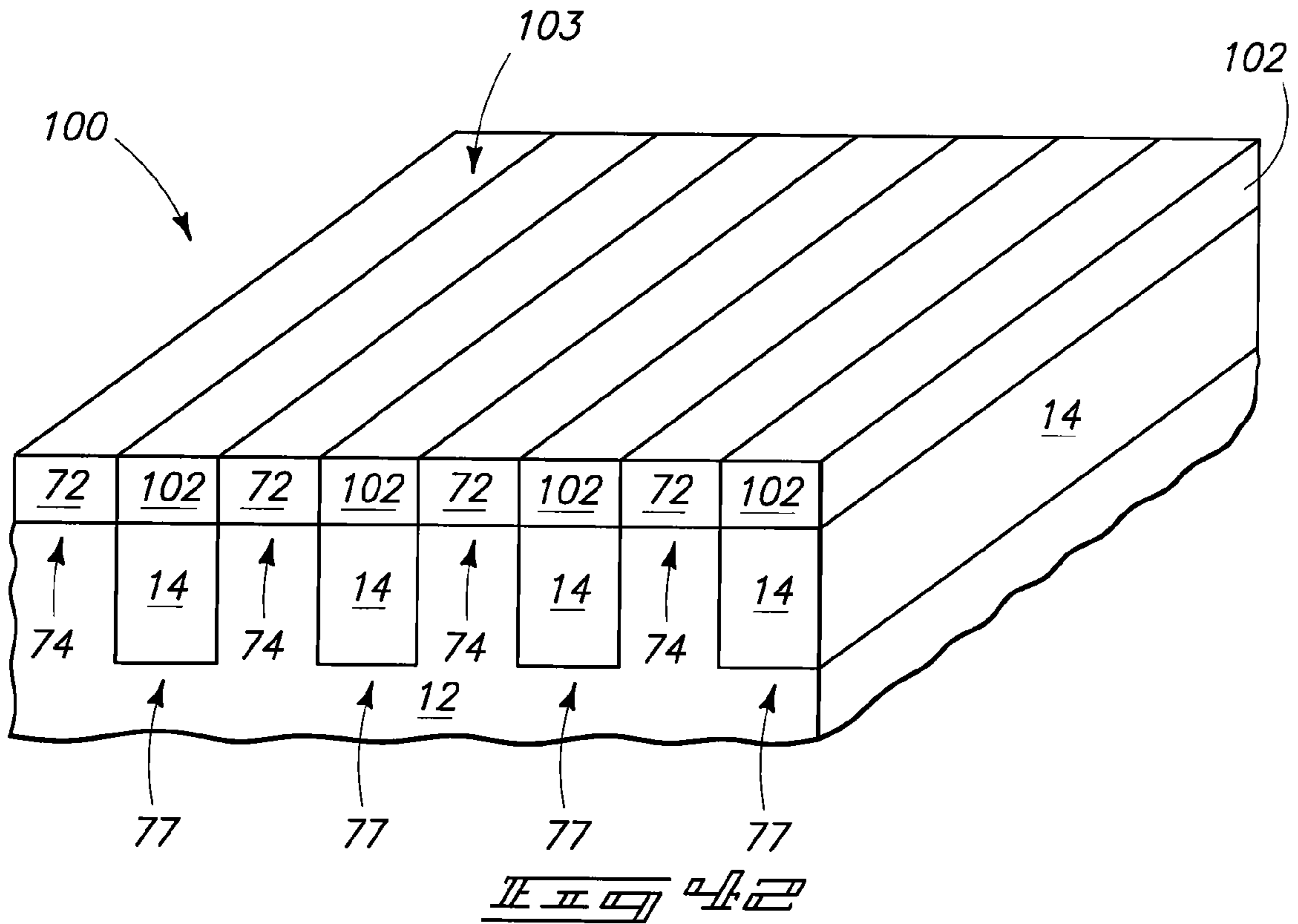
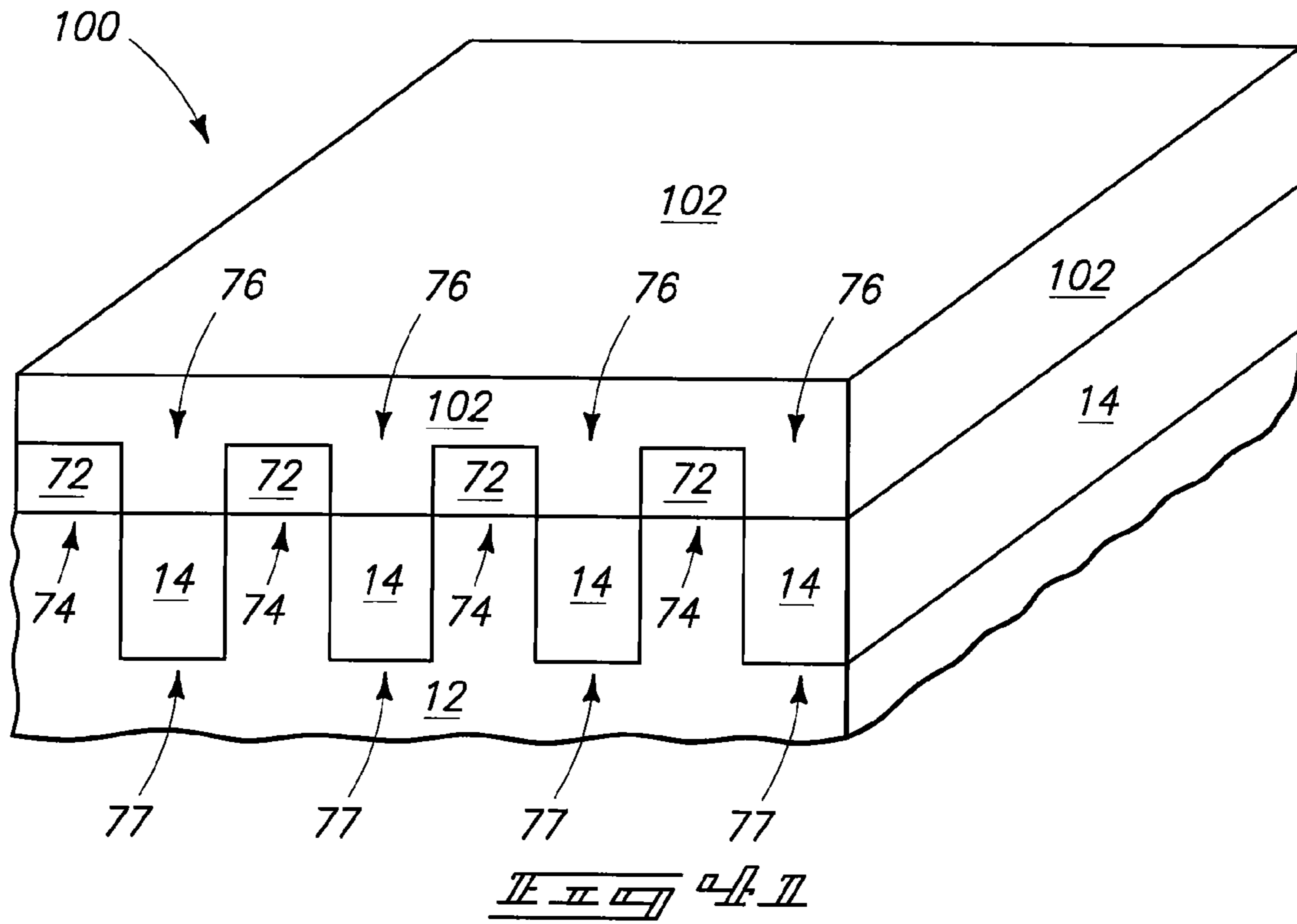
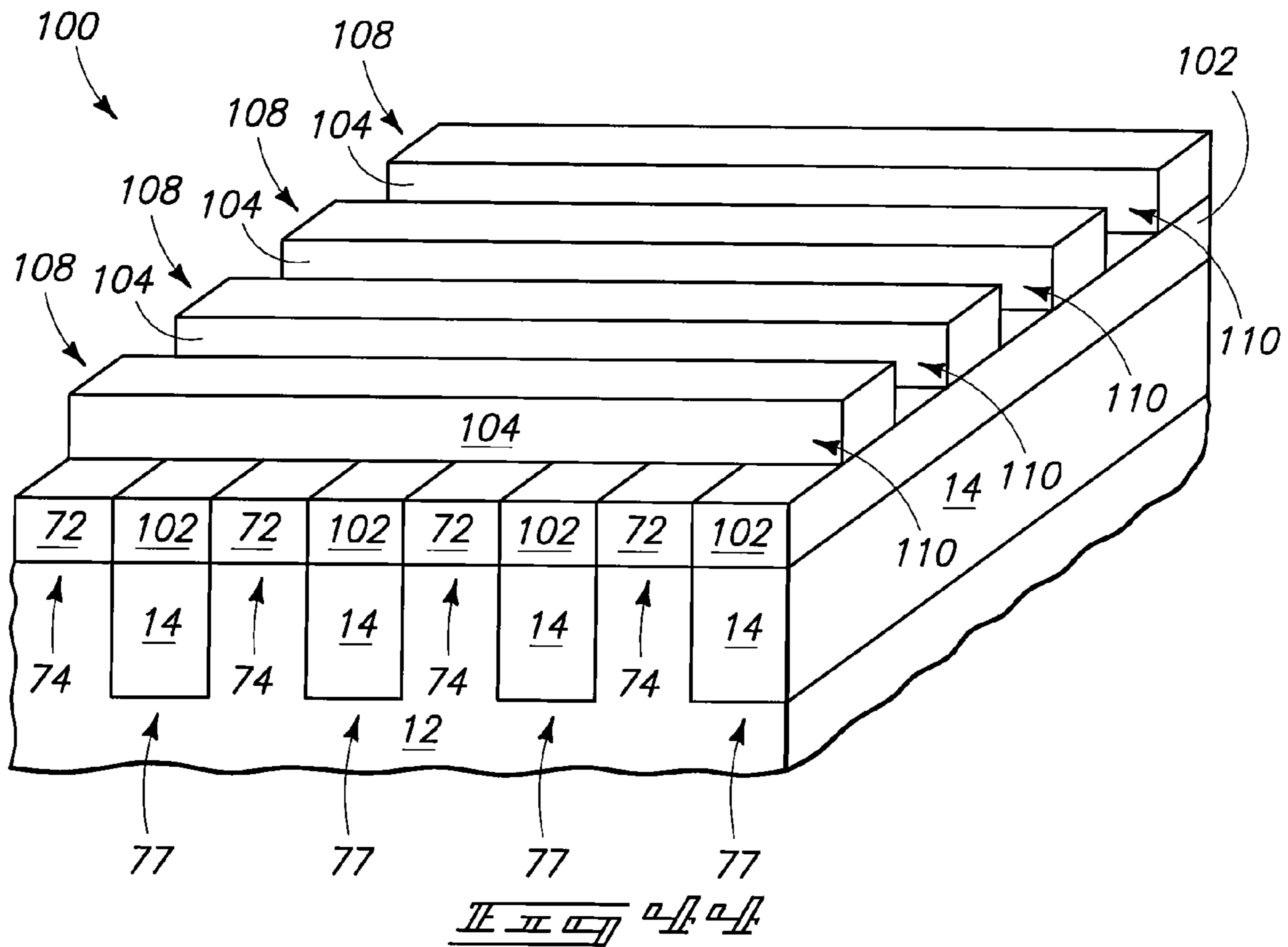
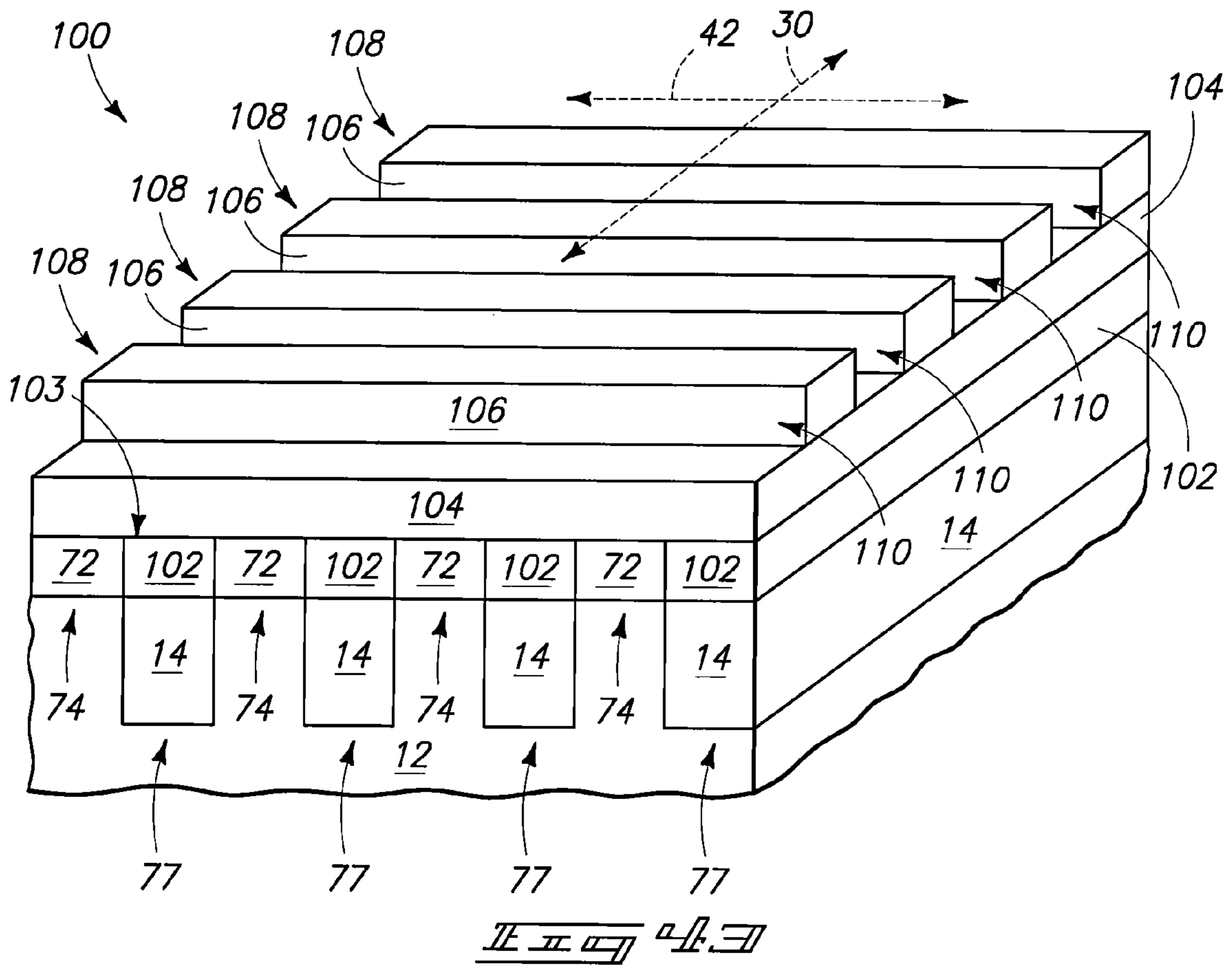
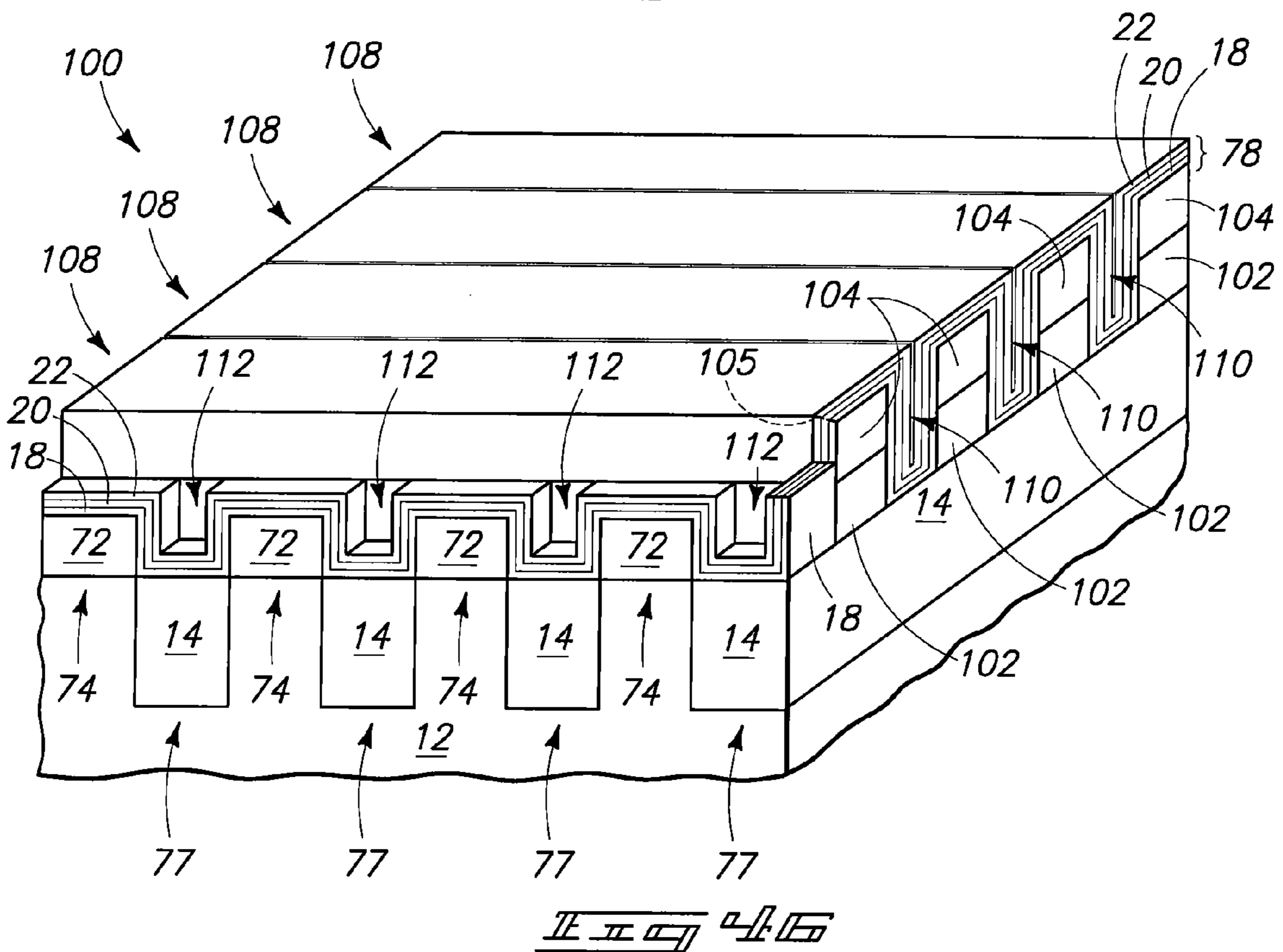
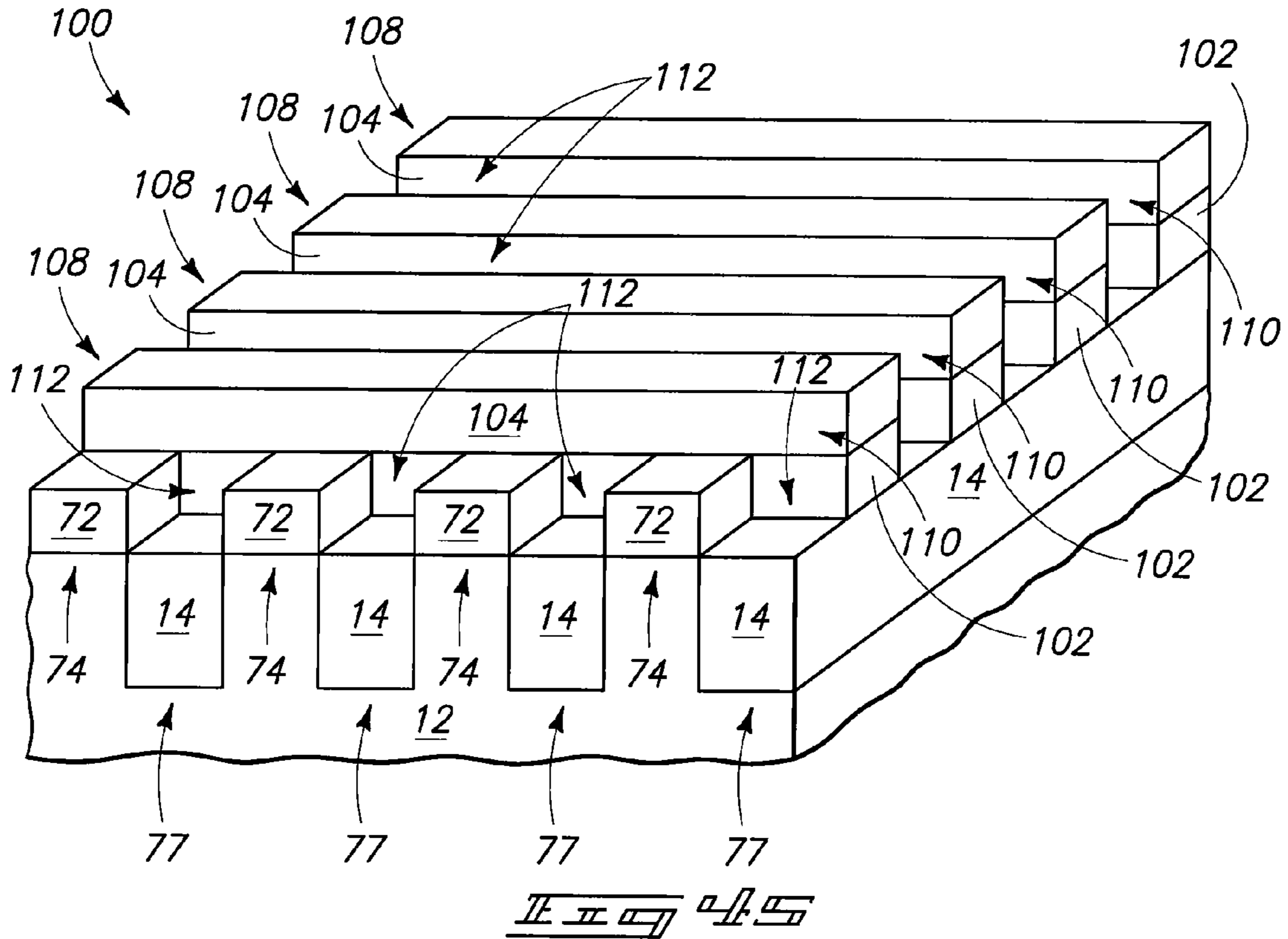


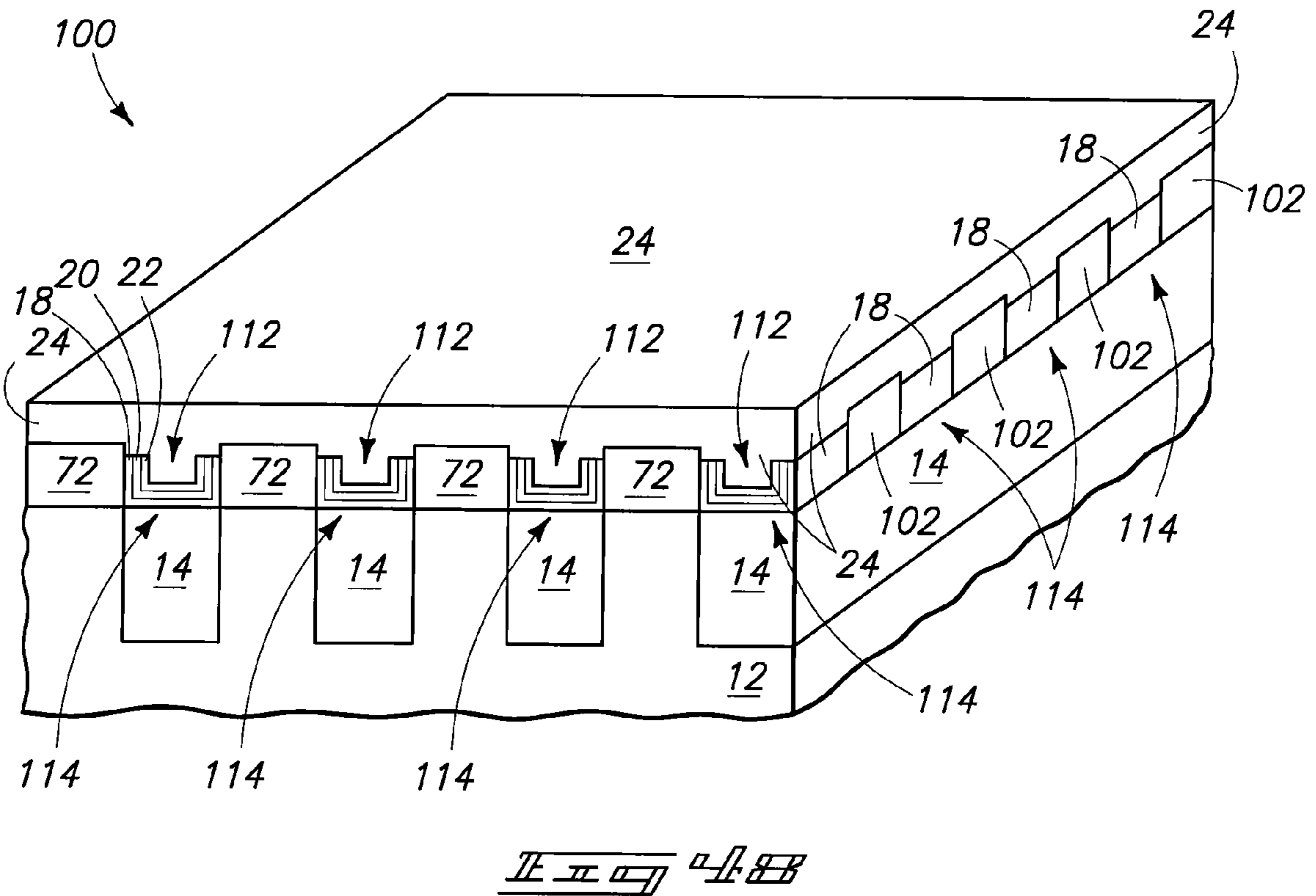
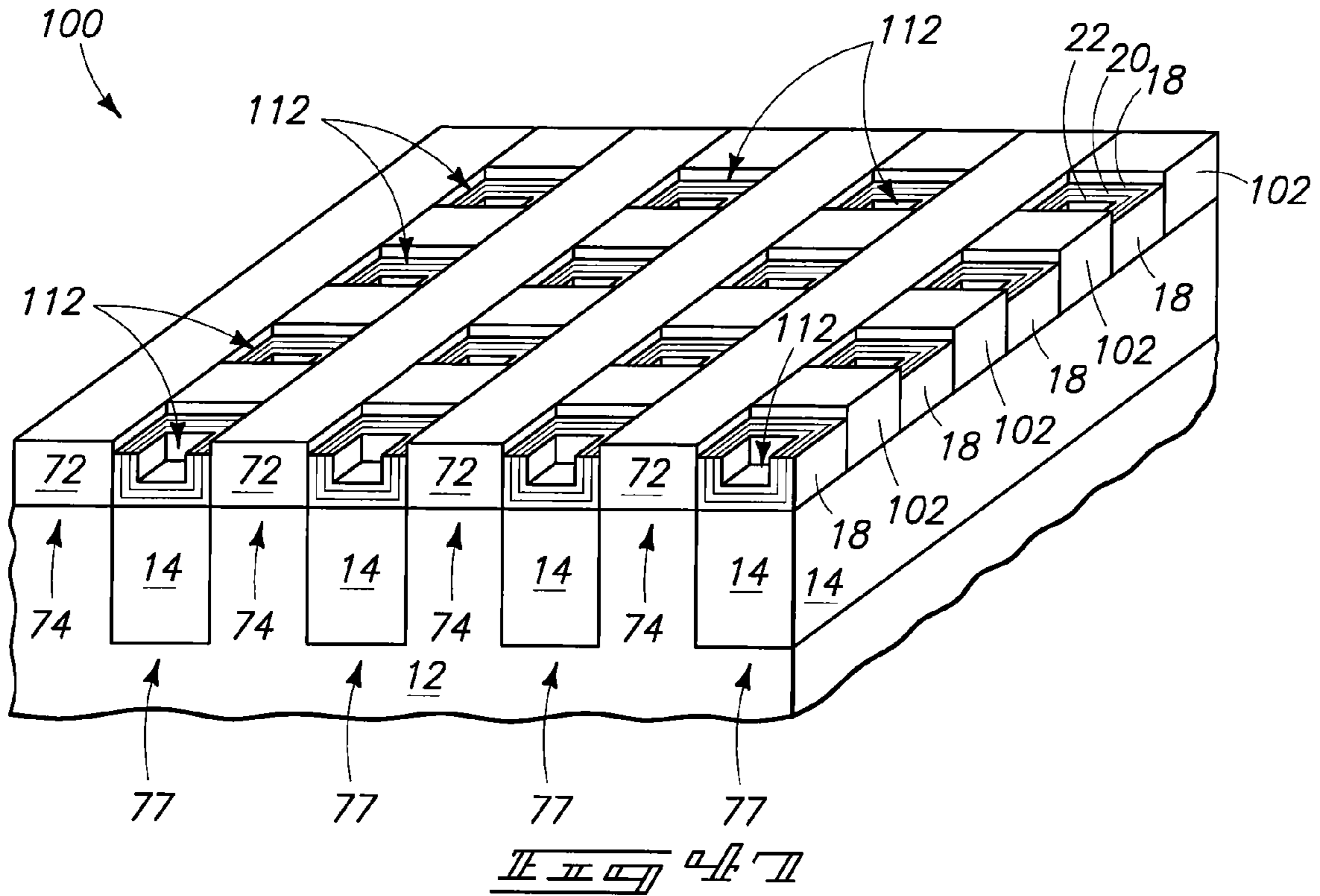
FIG. 3B



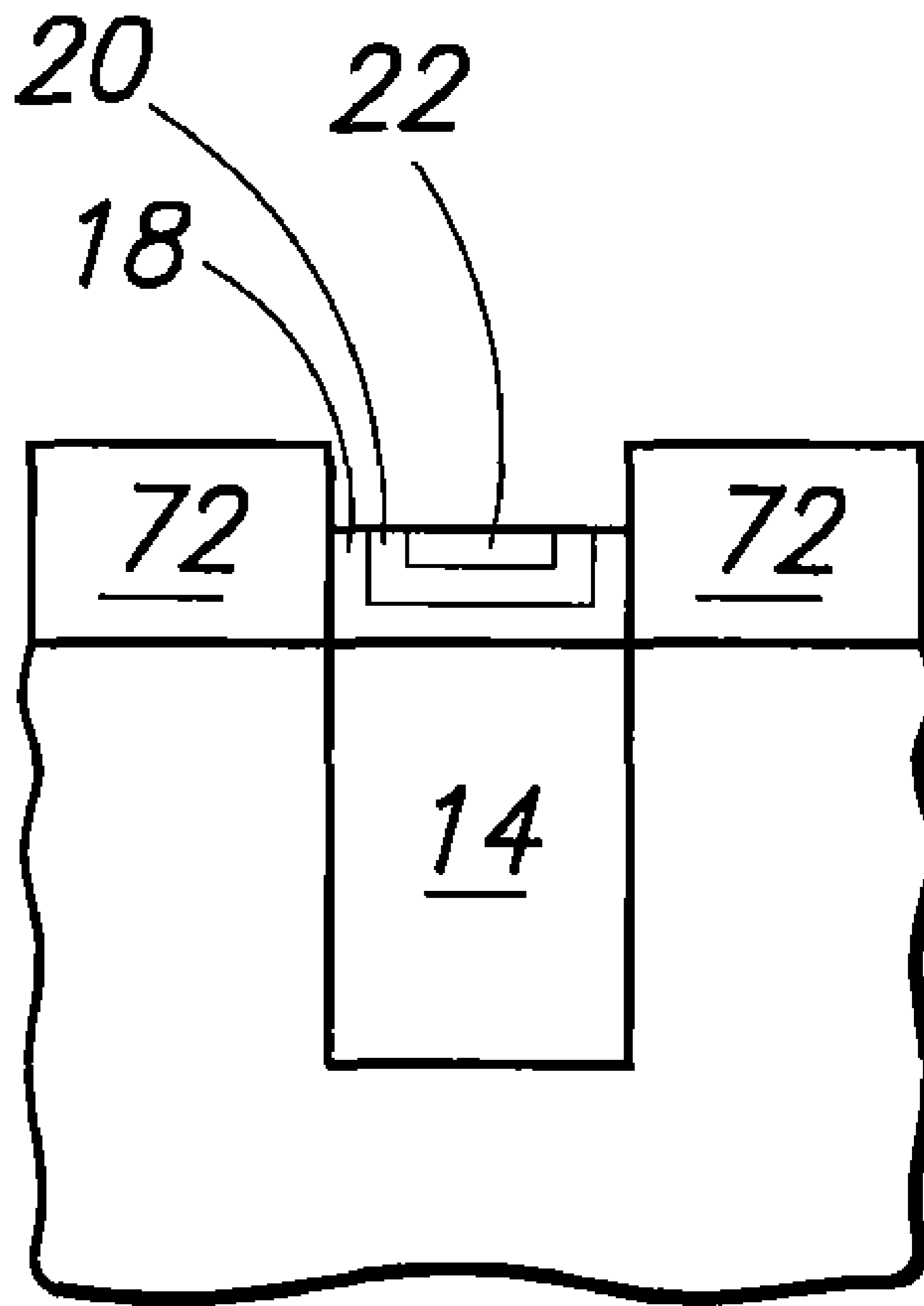
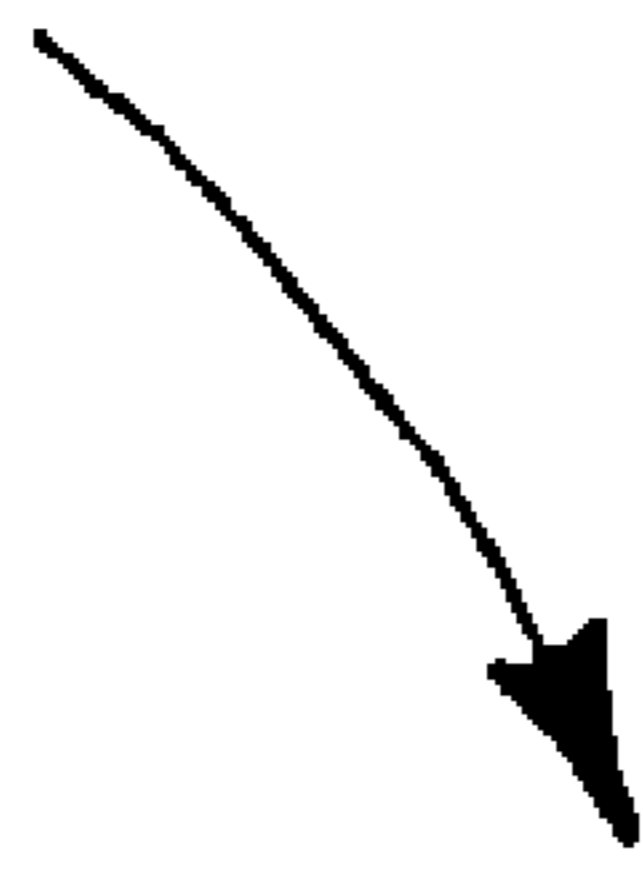








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1

METHODS OF FABRICATING A CROSS
POINT MEMORY ARRAY

TECHNICAL FIELD

Cross-point memory structures, and methods of forming memory arrays.

BACKGROUND

A continuing goal of integrated circuit fabrication is to decrease the amount of semiconductor real estate consumed by integrated circuit devices, and to thereby increase the level of integration.

Memory may utilize a large array of memory devices, with each memory device storing one or more data bits. Accordingly, reduction in the size of individual memory devices may translate into a large increase in the bit density. Common memory devices are dynamic random access memory (DRAM) devices, static random access memory (SRAM) devices, and nonvolatile devices (so-called flash devices). The nonvolatile devices may be incorporated into NAND or NOR memory array architectures.

The size of a memory device may be expressed in terms of the smallest feature size utilized in fabrication of the memory device. Specifically, if the smallest feature size is designated as "F", the memory device dimensions may be expressed in units of F. Conventional DRAM memory frequently comprises dimensions of at least $6F^2$, and SRAM may require even more semiconductor real estate.

A type of memory that potentially consumes very little semiconductor real estate is so-called cross-point memory. In cross-point memory, a memory cell occurs at overlap between a wordline and a bitline. Specifically, a memory element material is provided between the wordline and bitline. The memory element material comprises one or more substances which undergo stable and detectable change upon exposure to current; and may be, for example, a perovskite material, a chalcogenide material, an ionic transport material, a resistive switching material, a polymeric material and/or a phase change material. Since the memory cell may be confined to a region of overlap of a bitline and wordline, the memory cell may be theoretically formed to dimensions of $4F^2$ or less.

It is desired to develop improved methods for forming cross-point memory; and to develop improved cross-point memory structures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1-9 and 11 are diagrammatic, three-dimensional views of a portion of a construction at various process stages of an example embodiment process for forming a memory array.

FIG. 10 is a cross-sectional view along the line 10-10 of FIG. 9.

FIGS. 12, 13, 15-17, 19, 20 and 22 are diagrammatic, three-dimensional views of a portion of a construction at various process stages of another example embodiment process for forming a memory array. The process stage of FIG. 12 follows the processing stage of FIG. 4, and is alternative to that of FIG. 5.

FIG. 14 is a cross-sectional view along the line 14-14 of FIG. 13;

FIG. 18 is a cross-sectional view along the line 18-18 of FIG. 17; and

2

FIG. 21 is a cross-sectional view along the line 21-21 of FIG. 20.

FIG. 23 is a diagrammatic, three-dimensional view of a portion of a construction showing an embodiment of a cross-point memory structure.

FIGS. 24-35 are diagrammatic, three-dimensional views of a portion of a construction at various process stages of another example embodiment process for forming a memory array.

FIG. 36 is a diagrammatic, three-dimensional view of a portion of a construction showing another embodiment of a cross-point memory structure.

FIGS. 37-48 are diagrammatic, three-dimensional views of a portion of a construction at various process stages of another example embodiment process for forming a memory array.

FIG. 49 shows an example plug that may be formed with processing alternative to that shown in FIG. 29.

DETAILED DESCRIPTION OF THE
ILLUSTRATED EMBODIMENTS

Some embodiments include processing methods which may be utilized to form arrays of cross-point memory cells, and some embodiments include cross-point memory structures. Example embodiments are described with reference to FIGS. 1-48.

FIG. 1 shows a portion of a construction 10. The construction includes a base 12. The base may comprise an electrically insulative material, such as, for example, one or more of silicon dioxide, silicon nitride, and silicon oxynitride. Although the base is shown to be homogeneous, in some embodiments the base may comprise multiple layers and materials associated with the fabrication of integrated circuitry. For instance, the base may comprise the above-discussed insulative material supported over a semiconductor material. The semiconductor material may comprise, consist essentially of, or consist of monocrystalline silicon. If the base comprise a semiconductor material, base 12 may be referred to as a semiconductor substrate. The terms "semiconductive substrate" and "semiconductor substrate" mean any construction comprising semiconductive material, including, but not limited to, bulk semiconductive materials such as a semiconductive wafer (either alone or in assemblies comprising other materials thereon), and semiconductive material layers (either alone or in assemblies comprising other materials). The term "substrate" refers to any supporting structure, including, but not limited to, the semiconductive substrates described above. If base 12 is a semiconductor substrate, construction 10 may be referred to as a semiconductor construction.

A first electrode material (which may also be referred to as a bottom electrode material) 14 is formed over base 12. The first electrode material 14 physically contacts an upper surface of base 12.

First electrode material 14 may comprise any suitable composition or combination of compositions; and in some embodiments may comprise, consist essentially of, or consist of one or more compositions selected from the group consisting of platinum, titanium nitride and tantalum nitride.

A memory stack 16 is formed over the first electrode material 14. The memory stack comprises, in ascending order from the first electrode material, a first insulative material 18, a second insulative material 20, an electrically conductive material 22, and a memory element material 24.

The first and second insulative materials (18 and 20) together with the first electrode material 14 and the electrically conductive material 22 form a metal-insulator-insulator-metal (MIIM) diode. The electrically conductive material

22 may have a work function which is high relative to the work function of the first electrode material; and may, for example, comprise, consist essentially of, or consist of one or more compositions selected from the group consisting of tantalum silicon nitride, chromium and tantalum. The insulative materials may comprise any suitable compositions or combinations of compositions, and may be tailored relative to one another so that bandgaps, and/or conduction band edges, and/or valence band edges, between the materials enable tunneling of carriers in one direction, but not in an opposing direction. The insulative materials are thus compositionally different from one another, and each may, for example, comprise, consist essentially of, or consist of one or more compositions selected from the group consisting of aluminum oxide, silicon oxide, silicon nitride, zirconium oxide and hafnium oxide.

Although the shown diode is an MIIM diode, and thus comprises two insulative materials, in other embodiments the diode may comprise three or more insulative materials. The diode may be, for example, analogous to diodes described in US patent publication 2008/0273363. In some embodiments, one of the insulative materials may be a native oxide on the first electrode material.

The memory element material **24** may comprise any suitable composition or combination of compositions, and in some embodiments may be a perovskite material, a chalcogenide material, an ionic transport material, a resistive switching material, a polymeric material and/or a phase change material. If material **24** is a phase change material, the material may, for example, comprise, consist essentially, or consist of a mixture of germanium, antimony and tellurium.

A patterned masking material **28** is formed over memory element material **24**. The patterned masking material is in the form of a plurality of spaced lines **26**, with such lines extending primarily along a horizontal direction **30**. In the shown embodiment, all of the lines extend exactly along the horizontal direction **30**. In other embodiments the lines may have variation so that they extend mostly along horizontal direction **30**, but have some waviness or other features so that the lines do not extend entirely along the horizontal direction **30**. The term "primarily" in the phrase "extending primarily along the indicated horizontal direction" is used to indicate that the lines extend at least mostly along the indicated horizontal direction.

Masking material **28** may comprise any suitable composition or combination of compositions; and may, for example, comprise, consist essentially of, or consist of one or more of photoresist, amorphous carbon, transparent carbon, silicon dioxide, silicon nitride and silicon oxynitride. The material may be homogeneous (as shown), or may comprise a stack of two or more different compositions.

The spaced lines are separated from one another by gaps **32**.

In some embodiments, the spaced lines may be referred to as a first set of spaced lines, to distinguish the spaced lines from other lines that may be formed subsequently.

The lines **26** of masking material **28** may be formed with any suitable processing. In some embodiments, the lines may be formed by initially forming a layer of material **28** entirely across masking element **24**; forming a photolithographically-patterned mask over the layer of material **28**; transferring a pattern from the photolithographically-patterned mask into the underlying material **28** to form the lines **26** of such material; and then removing the photolithographically-patterned mask to leave the construction shown in FIG. 1. If material **28** includes photoresist, the material **28** may consist of photolithographically-patterned photoresist, or may comprise the

photolithographically-patterned photoresist mask over an underlying composition. In some embodiments, lines **26** may comprise sub-photolithographic resolution features that are formed using pitch multiplication techniques, e.g. spacer pitch-doubling or pitch-quadrupling techniques. In other embodiments, lines **26** may comprise sub-photolithographic resolution features that are formed using self-assembly or directed-assembly techniques, e.g. block copolymer microphase separation. In even other embodiments, lines **26** may comprise sub-photolithographic resolution features that are formed using particle beam lithography techniques, e.g. electron beam lithography.

Referring to FIG. 2, a pattern is transferred from patterned masking material **28** into first electrode material **14** and memory cell stack **16** with one or more etches, so that the first electrode material **14** and memory cell stack **16** adopt the pattern of the patterned masking material **28**. Specifically, the first electrode material **14** and memory cell stack **16** adopt the pattern of the first set of spaced lines **26** extending primarily along the first horizontal direction **30**. The patterning extends gaps **32** entirely through materials **14**, **18**, **20**, **22** and **24**; and to an upper surface of base **12**.

Referring to FIG. 3, a dielectric material **34** is formed over lines **26**, and within the gaps **32** between the lines. Dielectric material **34** may comprise any suitable composition or combination of compositions; and may, for example, comprise, one or more of silicon dioxide, silicon nitride, silicon oxynitride, and various doped silicon oxides (for instance, borophosphosilicate glass, borosilicate glass, fluorosilicate glass, etc.).

In the shown embodiment, masking material **28** remains over memory cell stack **16** during formation of dielectric material **34**. In other embodiments, masking material **28** may be removed prior to formation of dielectric material **34**.

Referring to FIG. 4, material **34** is removed from over lines **26**. Such removal may be accomplished utilizing any suitable processing. For instance, the removal may be accomplished utilizing an etch-back and/or planarization (for instance, chemical-mechanical polishing [CMP]). In the shown embodiment, such removal is accomplished utilizing planarization to form a planarized upper surface **35** extending across materials **28** and **34**.

Referring to FIG. 5, patterned masking materials **36** and **38** are formed over lines **26** and over the dielectric material **34** in the gaps between lines **26**. The patterned masking materials **36** and **38** comprise a plurality of lines **40** extending primarily along a second horizontal direction **42** orthogonal to the first horizontal direction **30**. The lines **40** may be referred to as a second set of lines to distinguish them from the first set of lines **26**.

Material **36** may correspond to a so-called hard masking material, and may comprise any of the compositions discussed above regarding masking material **28**.

Material **38** may correspond to photolithographically-patterned photoresist.

Patterned lines **40** may be formed by initially forming a layer of material **36** entirely across upper surface **35** (FIG. 4), forming photolithographically-patterned photoresist **38** over the layer of material **36**, and then transferring a pattern from the photolithographically-patterned photoresist into material **36** with one or more etches.

Lines **40** are spaced from one another by gaps **44**. After lines **40** are formed, material **28** is removed from within gaps **44** by one or more suitable etches.

Referring to FIG. 6, material **38** (FIG. 5) is removed from lines **40**.

5

Referring to FIG. 7, top electrode material 46 is formed over lines 40 and within the gaps 44 between lines 40. Top electrode material 46 may comprise any suitable composition or combination of compositions; and in some embodiments may comprise one or more of various metals (platinum, palladium, tungsten, titanium, etc.), metal-containing compositions (metal nitride, metal suicides, etc.) and conductively-doped semiconductor materials (conductively-doped silicon, conductively-doped germanium, etc.).

Referring to FIG. 8, top electrode material 46 is removed from over lines 40. Such removal may be accomplished utilizing any suitable processing. For instance, the removal may be accomplished utilizing an etch-back and/or planarization (for instance, CMP). In the shown embodiment, such removal is accomplished utilizing planarization to form a planarized upper surface 47 extending across materials 46 and 36.

The top electrode material 46 remaining at the processing stage of FIG. 8 is in the form of a plurality of spaced lines 48 formed within the gaps 44 between lines 40. In some embodiments, lines 48 may be referred to as a second set of spaced electrically-conductive lines to distinguish them from the first set of spaced electrically-conductive lines 26 of electrode material 14. In some embodiments, lines 26 may be referred to as a first set of spaced lines, lines 40 may be referred to as a second set of spaced lines, and lines 48 may be referred to as a third set of spaced lines.

Referring to FIGS. 9 and 10, material 36 (FIG. 8) is removed from between lines 48; and subsequently the materials 18, 20, 22 and 24 of memory cell stacks 16 are removed from the regions between the lines 48. The removal of materials 18, 20, 22 and 24 from between lines 48 forms the remaining materials 18, 20, 22 and 24 into an array of memory unit cells 50 (only some of which are labeled). The individual memory unit cells comprise memory cell stack 16 between the first electrode material 14 and the second electrode material 46.

Referring to FIG. 11, dielectric material 52 is formed over lines 48, and within gaps between the lines 48. Dielectric material 52 may be referred to as a second dielectric material to distinguish it from the first dielectric material 34. Dielectric material 52 may comprise any of the compositions discussed above regarding dielectric material 34. In some embodiments, dielectric material 52 may be a same composition as dielectric material 34; and in other embodiments may be a different composition from dielectric material 34. In some embodiments, dielectric material 52 may be considered to replace the spaced lines 40 that had been between the spaced lines 48 of the first electrode material 46 at an earlier processing stage (FIG. 8).

The processing of FIGS. 1-11 removes conductive material 22 of the memory cell stack 16 after formation of the lines 48 of top electrode material 46. Specifically, the lines 48 are utilized as a mask during etching of the materials of the memory cell stack 16. In other embodiments, at least some of materials of the memory cell stack may be removed prior to forming the top electrode material. FIGS. 12-22 illustrate an example embodiment in which materials of a memory cell stack are removed prior to forming top electrode material 46.

Referring to FIG. 12, construction 10 is shown at a processing stage subsequent to that of FIG. 4, and analogous to that of FIG. 5. However, unlike the processing stage of FIG. 5, the materials of memory cell stack 16 are removed from between lines 40 of patterned masking materials 36 and 38. In the shown embodiment, all of the materials of the memory cell stack are removed between lines 40. However, as long as conductive material 22 and memory element material 24 are removed from between the lines 40, an array of isolated

6

memory cells may be formed. Accordingly, in some embodiments it is only materials 22 and 24 that are removed between lines 40; and in other embodiments it may be materials 20, 22 and 24 removed from between lines 40; and in yet other embodiments all of materials 18, 20, 22 and 24 of the memory cell stacks 16 may be removed from between lines 40 (as shown).

In some embodiments, material 36 is a sacrificial material utilized to define a location for a top electrode material 46 (shown in FIGS. 19 and 20). In other embodiments, material 36 may be a conductive material (i.e., a conductive hard mask), and may be utilized as a top electrode. In embodiments in which material 36 is utilized as a top electrode, material 28 may be removed prior to formation of material 36; and processing discussed below with reference to FIGS. 16-22 may be modified, or omitted. If material 36 is a conductive hard mask material, the material 36 may be considered to be patterned into a plurality of conductive lines 37.

Referring to FIGS. 13 and 14, masking material 38 (FIG. 12) is removed with processing analogous to that discussed above with reference to FIG. 6.

Referring to FIG. 15, a dielectric material 54 is deposited over and between lines 40. Dielectric material 54 may comprise any of the compositions discussed above regarding dielectric material 34. In some embodiments, dielectric material 54 may be a same composition as dielectric material 34; and in other embodiments may be a different composition from dielectric material 34.

Referring to FIG. 16, material 54 is removed from over lines 40. Such removal may be accomplished utilizing any suitable processing. For instance, the removal may be accomplished utilizing an etch-back and/or planarization (for instance, CMP). In the shown embodiment, such removal is accomplished utilizing planarization to form a planarized upper surface 55 extending across materials 36 and 54.

Referring to FIGS. 17 and 18, materials 28 and 36 are removed to leave gaps 56 extending within dielectric materials 34 and 54. The gaps 56 are trenches extending along the second horizontal direction 42.

Referring to FIG. 19, top electrode material 46 is formed over dielectric material 54 and within gaps 56.

Referring to FIGS. 20 and 21, top electrode material 46 is removed from over dielectric material 54. Such removal may be accomplished utilizing any suitable processing. For instance, the removal may be accomplished utilizing an etch-back and/or planarization (for instance, CMP). In the shown embodiment, such removal is accomplished utilizing planarization to form a planarized upper surface 57 extending across materials 46 and 54.

The top electrode material 46 remaining at the processing stage of FIGS. 20 and 21 is in the form of a plurality of spaced lines 58 formed within the gaps 56 (FIG. 19). A difference between the processing of FIGS. 12-21 and that of FIGS. 5-9 is that the top electrode lines 58 of the processing of FIGS. 12-21 are formed at the locations of masking material 36 (FIG. 16), whereas the top electrode lines 48 of the processing of FIGS. 5-9 are formed within spaces between the locations of masking material 36 (FIG. 8).

Referring to FIG. 22, a dielectric material 60 is formed over lines 58 of top electrode material 46 as an electrically insulative cap. Dielectric material 60 may comprise any of the compositions discussed above regarding dielectric materials 34 and 54. In some embodiments, dielectric material 60 may be the same composition as at least one of dielectric materials 34 and 54; and in other embodiments dielectric material 60 may be compositionally different from both of materials 34 and 54.

Regardless of whether the processing of FIGS. 5-11 is followed, or the processing of FIGS. 12-15 is followed with material 36 being a conductive hard mask utilized as a top electrode, or the processing FIGS. 12-22 is followed with material 36 being a sacrificial material used to define a location of a top electrode, memory arrays will be formed comprising cross-point memory unit cells; with the memory cells having the same configuration from the various processing sequences. An example memory cell structure 62 formed by the processing of FIGS. 5-11, FIGS. 12-15 with material 36 being a conductive hard mask, or that of FIGS. 12-22, is shown in FIG. 23. The memory cell structure includes a line 26 of bottom electrode material 14 extending along a first horizontal direction, and a line 37, 48, 58 of top electrode material 36, 46 extending along a second horizontal direction which is perpendicular to the first horizontal direction. The line of top electrode material will be a line 37 if processing of FIGS. 12-15 is followed with a conductive hard mask material 36, a line 48 of material 46 if the processing of FIGS. 5-11 is followed, and will be a line 58 of material 46 if the processing of FIGS. 12-22 is followed with material 36 being a sacrificial material.

A memory cell 50 is sandwiched between the top and bottom electrodes. The memory cell includes the memory element material 24; and includes materials 18, 20 and 22 as part of an access device configured for accessing data stored within memory element material 24. The shown access device is an MIIM diode, with electrode 14 and electrically conductive material 22 being the outer components of the diode; and with the insulators 18 and 20 being the inner components of the diode.

Another process for forming a memory array is described with reference to FIGS. 24-36. Identical number will be used to describe the embodiment of FIGS. 24-36 as is used above in describing the embodiments of FIGS. 1-23, where appropriate.

FIG. 24 shows a construction 70 at a processing stage after a patterned masking material 72 has been formed across a base 12. The patterned masking material is in the form of a plurality of spaced lines 74, with such lines extending primarily along the horizontal direction 30. Masking material 72 may comprise any of the compositions described above relative to masking material 28 of FIG. 1.

The spaced lines 74 are separated from one another by gaps 76, which may be referred to as trenches between the lines 74.

The lines 74 of masking material 72 may be formed with any suitable processing. In some embodiments, the lines may be formed by initially forming a layer of material 72 entirely across base 12; forming a photolithographically-patterned mask over the layer of material 72; transferring a pattern from the photolithographically-patterned mask into the underlying material 72 to form the lines 74 of such material; and then removing the photolithographically-patterned mask to leave the construction shown in FIG. 24.

Referring to FIG. 25, a pattern is transferred from patterned masking material 72 into base 12 to extend the trenches 76 into the base.

Referring to FIG. 26, bottom electrode material (or first electrode material) 14 is formed over lines 74 and within the trenches 76 to fill the trenches.

Referring to FIG. 27, bottom electrode material 14 is removed from an upper region of trenches 76, while leaving the bottom electrode material within a lower region of the trenches. The bottom electrode material 14 remaining in the lower region of the trenches forms a plurality of spaced apart lines 77 extending along the first horizontal direction 30. In the shown embodiment, the bottom electrode material fills

trenches 76 to a level that is about even with an upper surface of substrate 12. In different embodiments, the bottom electrode material may fill the trenches to a different level; and specifically may fill the trenches to a level beneath an upper surface of base 12 in some embodiments, or may fill the trenches to a level above the upper surface of base 12 in other embodiments. In some embodiments, the bottom electrode material may be a conformal coating, such as, for example, a film formed by atomic layer deposition.

Referring to FIG. 28, a stack 78 of access device materials is formed within the remaining upper regions of the trenches 76 to partially fill such regions of the trenches. The stack 78 includes insulative materials 18 and 20, as well as electrically conductive material 22. Although the access device materials are shown to include a pair of insulative materials, in other embodiments the access device materials may contain more than two insulative materials. In some embodiments, the first insulative material 18 may be native oxide formed along the bottom electrode material.

The access device materials are formed conformally over lines 74 and within trenches 76 so that the stack 78 has an undulating upper topography.

Referring to FIG. 29, the materials 18, 20 and 22 are removed from over lines 74 with etching and/or polishing. If etching is utilized, such etching may comprise a plasma etch. If polishing is utilized, such polishing may comprise CMP.

Electrically conductive material 22 is recessed within trenches 76 so that an upper surface of the electrically conductive material is below the uppermost surfaces of lines 72. In the shown embodiment, all of the materials 18, 20 and 22 are recessed. Such recessing may be accomplished during an etch utilized to remove materials 18, 20 and 22 from over lines 74; or may be accomplished with an etch conducted subsequent to removal of materials 18, 20 and 22 from over lines 74. In some embodiments, the access device materials remaining within the trenches at the processing stage of FIG. 29 may be considered to comprise sidewall regions along sidewalls of the trenches, and to comprise bottom regions along bottoms of the trenches; and the recessing of materials 18, 20 and 22 may be considered to comprise recessing the sidewall regions of the access device materials to a level beneath an upper level of the material 72 along the peripheries of the trenches. In some embodiments, the recessing may be conducted to remove all of materials 18, 20 and 22 from the sidewalls of the opening to leave a block of materials 18, 20 and 22 at the bottoms of the openings, and such blocks may have planarized upper surfaces extending across materials 18, 20 and 22. An example block is shown in FIG. 49.

Referring to FIG. 30, memory element material 24 is formed within trenches 76 in a processing stage following that of FIG. 29. The memory element material may be formed in the shown configuration by initially providing the memory element material over lines 74 as well as within the trenches; and then utilizing planarization (for instance, CMP) to remove the memory element material from over the lines, while leaving the memory element material within the trenches. The memory element material remaining within the trenches may be considered to correspond to a plurality of spaced-apart lines that are in one-to-one correspondence with the trenches.

In the shown embodiment, the memory element material within trenches 76 has an upper portion 78 extending across uppermost of materials 18, 20 and 22; and has a plug portion 80 extending downwardly from the upper portion and into a container defined by materials 18, 20 and 22. The plug portion has downwardly-extending sidewalls 81 and 83, and has a bottom 85 joined to the downwardly-extending sidewalls.

The conductive material **22** extends along both of the downwardly-extending sidewalls **83** of the plugs, as well as along the bottoms **85** of such plugs.

Referring to FIG. **31**, top electrode material (or second electrode material) is formed over memory element material **24**, and over material **72** of lines **74**.

Referring to FIG. **32**, masking material **36** is formed over top electrode material **46**, and patterned masking material **38** is formed over material **36**. Material **38** may correspond to photolithographically-patterned photoresist, and is formed in the pattern of the plurality of spaced-apart lines **40** analogous to that which was discussed above with reference to FIG. **5**. The lines **40** extend along the second horizontal direction **42** which is orthogonal to the first horizontal direction **30**.

The lines **40** are spaced from one another by gaps **44**.

Referring to FIG. **33**, a pattern is transferred from material **38** (FIG. **32**) through underlying materials **72**, **18**, **20**, **22**, **24**, **36** and **46**, to pattern such underlying materials into the configuration of the plurality of lines **40** extending along the horizontal direction **42**; and then masking material **38** is removed. Such patterning may comprise transferring a pattern from masking material **38** into hard mask **36**, removal of masking material **38**, and then transfer of the pattern from hard mask **36** into the underlying materials **72**, **18**, **20**, **22**, **24** and **46** with one or more suitable etches. The patterning forms the top electrode material **46** into a plurality of electrode lines **48**, with such electrode lines **48** being part of the lines **40**.

Referring to FIG. **34**, masking material **36** is removed. Such removal may be accomplished with an etch, CMP, and/or a wet clean.

Referring to FIG. **35**, dielectric material **90** is formed over top electrode lines **48** and within the gaps **44** between such lines. Dielectric material **90** may comprise any of the compositions discussed above with reference to dielectric material **34** of FIG. **3**.

Although material **36** (FIG. **33**) is removed prior to formation of dielectric material **90** in the shown embodiment, in other embodiments material **36** may remain at the processing stage of FIG. **35**.

The construction of FIG. **35** comprises a memory array which includes a plurality of cross-point memory structures. An example of the memory structures is shown in FIG. **36** as a structure **92**.

The memory cell structure includes a line **77** of bottom electrode material **14** extending along a first horizontal direction, and a line **48** of top electrode material **46** extending along a second horizontal direction which is perpendicular to the first horizontal direction.

The memory cell structure also includes the memory element material **24**, the insulative materials **18** and **20**, and the electrically conductive material **22**. The materials **18**, **20** and **22** are part of an access device configured for accessing data stored within memory element material **24**. The access device is an MIIM diode, with electrode **14** and electrically conductive material **22** being the outer components of the diode; and with the insulators **18** and **20** being the inner components of the diode.

In the shown embodiment, the memory element material **24** includes the upper portion **78** extending across uppermost of materials **18**, **20** and **22**; and the plug portion **80** extending downwardly from the upper portion and into a container defined by materials **18**, and **22**. The plug portion has the downwardly-extending sidewalls **81** and **83**, and has the bottom **85** joined to the downwardly-extending sidewalls. The conductive material **22** extends along both of the downwardly-extending sidewalls **83** of the plug, as well as along the bottom **85** of such plug.

The materials **18**, **20** and **22** may be together considered to correspond to diode material. In some embodiments, the materials **18**, **20** and **22** are components of an access device utilized for accessing data stored in the memory element. Accordingly, the embodiment of FIG. **36** may be considered to comprise a multi-sided container of access device materials (with such multi-sided container specifically comprising two sides in the embodiment of FIG. **36**); and to comprise the plug **80** of memory element material extending into such multi-sided container.

In the shown embodiment, memory element material **24** has an uppermost region **78** that extends across uppermost surfaces of all of the materials **18**, **20** and **22** (with such uppermost surfaces being labeled **19**, **21** and **23** in FIG. **36**). However, as discussed above with reference to FIG. **29**, the invention may include embodiments in which material **22** is recessed within a trench, without recessing one or both of the materials **18** and **20**. In such embodiments, the upper portion **78** of memory element material **24** would not extend over the upper surface of the materials which were not recessed within the trench, and accordingly may be over an uppermost surface of electrically conductive material **22** while not being over uppermost surfaces of one or both of materials **18** and **20**. If the processing of FIG. **49** is utilized instead of that of FIG. **29**, a memory cell analogous to the structure **92** may be formed, but with a different configuration of materials **18**, **20**, **22** and **24**.

Another process for forming a memory array is described with reference to FIGS. **37-48**. Identical number will be used to describe the embodiment of FIGS. **37-48** as is used above in describing the embodiments of FIGS. **1-36**, where appropriate.

FIG. **37** shows a construction **100** at a processing stage identical to that discussed above with reference to FIG. **24**. Accordingly, the patterned masking material **72** has been formed across a base **12**. The patterned masking material is in the form of a plurality of spaced apart lines **74**, with such lines extending primarily along the horizontal direction **30**. The spaced apart lines **74** are separated from one another by gaps **76**, which may be referred to as trenches between the lines **74**.

Referring to FIG. **38**, construction **100** is shown at a processing stage identical to that discussed above with reference to FIG. **25**. Accordingly, a pattern has been transferred from patterned masking material **72** into base **12** to extend the trenches **76** into the base.

Referring to FIG. **39**, construction **100** is shown at a processing stage identical to that discussed above with reference to FIG. **26**. Accordingly, bottom electrode material (or first electrode material) **14** is formed over lines **74** and within the trenches **76** to fill the trenches.

Referring to FIG. **40**, construction **100** is shown at a processing stage identical to that discussed above with reference to FIG. **27**. Accordingly, bottom electrode material **14** is removed from an upper region of trenches **76**, while leaving the bottom electrode material within a lower region of the trenches. The bottom electrode material **14** remaining in the lower region of the trenches forms the plurality of spaced apart lines **77** extending along the first horizontal direction **30**.

Referring to FIG. **41**, an etch stop layer **102** is formed over lines **74** and within trenches **76**. The etch stop material may comprise any suitable composition or combination of compositions; and may, for example, comprise, consist essentially of, or consist of silicon dioxide, silicon nitride or silicon oxynitride.

Referring to FIG. **42**, material **102** is removed from over material **72** with one or both of etching and polishing. In the

11

shown embodiment, material 102 has been removed with CMP to leave a planarized surface 103 extending across materials 72 and 102.

Referring to FIG. 43, a masking material 104 is formed over surface 103, and patterned masking material 106 is formed over material 104. Material 106 may correspond to photolithographically-patterned photoresist, and is formed in a pattern of a plurality of spaced-apart lines 108 extending along the second horizontal direction 42 which is orthogonal to the first horizontal direction 30.

The lines 108 are spaced from one another by gaps 110.

Material 104 may comprise any of the compositions discussed above relative to material 28 of FIG. 1. Material 104 may be of a common composition to material 72 in some embodiments, and may be compositionally different from material 72 in other embodiments.

Referring to FIG. 44, a pattern is transferred from material 106 (FIG. 43) through underlying material 104 to pattern such underlying material into the configuration of the plurality of lines 108 extending along the horizontal direction 42; and then masking material 106 is removed. Such patterning may be considered to comprise extending gaps 110 into material 104.

Some of the material 102 is exposed within the gaps 110. FIG. 45 shows construction 100 after the exposed portions of material 102 have been removed. Such removal creates openings 112 (only some of which are labeled) that extend to an upper surface of the bottom electrode material 14. As discussed above with reference to FIG. 40, the lines 74 of material 72 may be considered to be spaced from one another by trenches (or gaps) 76 (shown in FIG. 40). Similarly, the lines 108 of material 104 may be considered to be spaced from one another by gaps 110. Accordingly, the openings 112 may be considered to correspond to locations where gaps 110 overlap gaps 76 (shown in FIG. 40).

The openings 112 may be considered to be examples of polygonal openings, and in the shown embodiment are four-sided openings.

The openings 112 are in a many-to-one arrangement with the lines 77 of bottom electrode material 14. In other words, there are many openings 112 along each of the individual lines.

Referring to FIG. 46, a stack 78 of access device material is formed over materials 72 and 104, and within the openings 112. The stack 78 only partially fills the openings 112. The stack 78 includes insulative materials 18 and 20, as well as electrically conductive material 22. Although the stack 78 is shown to include a pair of insulative materials, in other embodiments the stack 78 may contain more than two insulative materials. In some embodiments, the insulative material 18 may correspond to native oxide grown over the bottom electrode. The drawing of FIG. 46 is somewhat confusing in that the materials 18, 20 and 22 along the rightmost edge of the drawing join two different planes to one another. A dashed line 105 is provided to indicate where the view of the materials 18, and 22 along the rightmost edges changes from one plane to another. Also, there is an illusion along the rightmost edge that appears to show gaps 110 pinched relative to openings 112. Such illusion results from the direction along the cross-section of the rightmost edge, and in actual practice the gaps 110 may correspond identically to the widths along one side of the openings 112.

Referring to FIG. 47, the materials 104, 18, 20 and 22 are removed from over materials 72 and 102 with etching and/or polishing. If etching is utilized, such etching may comprise a plasma etch. If polishing is utilized, such polishing may comprise CMP. The removal of materials 104, 18, 20 and 22 from

12

over materials 72 and 102 leaves the materials 18, 20 and 22 only within openings 112, and leaves the openings 112 laterally bounded by materials 72 and 102. Materials 72 and 102 are different from one another so that material 102 could be selectively removed relative to material 72 at the processing stage of FIG. 45. Thus, the openings 112 at the processing stage of FIG. 47 may be considered to be bounded by two types of material (with one of the materials corresponding to material 72, and the other corresponding to material 102). Two of the four sides of the openings 112 will be laterally bounded by one of said two types of material, and the other two of the four sides will be laterally bounded by the other of said two types of material.

Electrically conductive material 22 is recessed within openings 112 so that an upper surface of the electrically conductive material is below the uppermost surfaces of materials 72 and 102. In the shown embodiment, all of the materials 18, 20 and 22 are recessed. Such recessing may be accomplished during an etch utilized to remove materials 18, 20 and 22 from over materials 72 and 102; or may be encompassed with an etch conducted subsequent to removal of materials 18, 20 and 22 from over materials 72 and 102. In some embodiments, the access device material remaining within the openings 112 at the processing stage of FIG. 47 may be considered to comprise sidewall regions along sidewalls of the openings 112, and to comprise bottom regions along bottoms of the openings; and the recessing of access device materials 18, 20 and 22 may be considered to comprise recessing the sidewall regions of the access device materials to a level beneath an upper level of the materials 72 and 102 along the peripheries of openings 112. In some embodiments, the recessing may remove all of materials 18, 20 and 22 from along the sidewalls, analogously to the processing discussed above with reference to FIG. 49.

Referring to FIG. 48, memory element material 24 is formed within openings 112 and over materials 72 and 102.

In the shown embodiment, the memory element material within openings 112 has plug portions 114 extending downwardly into containers defined by materials 18, 20 and 22. The plug portions have four downwardly-extending sidewalls analogous to the sidewalls 81 and 83 of FIG. 36 (with such plug portions of the embodiment of FIG. 48 being defined by the four sides of the containers formed by materials 18, 20 and 22 within openings 112, with such containers being visible in the top view of FIG. 47), and have bottoms joined to the downwardly-extending sidewalls. The conductive material 22 extends along the downwardly-extending sidewalls of the plug portions, as well as along the bottoms of such plug portions.

In subsequent processing (not shown), the memory element material may be subjected to planarization (for instance, CMP) to remove the memory element material from over the materials 72 and 102, while leaving the memory element material within the openings 112. Top electrode material analogous to the electrode material 46 of FIG. 31 may be then formed over memory element material, and patterned to form a plurality of top electrode lines analogous to the lines 48 of FIG. 34. Such patterning may utilize processing analogous to that discussed above with reference to FIGS. 31-35. The construction 100 of FIG. 48 may thus be utilized to form memory cell structures analogous to the structure of FIG. 36, but where a plug portion of a memory element material is within a four-sided container of access device material, rather than within a two-sided container of the access device material. The two-sided and four-sided containers of FIGS. 36 and 48 are examples of multi-sided containers that may be formed in some embodiments of the invention. The number of sides

13

of multi-sided openings may be varied in other embodiments (not shown), and the lengths of the sides may be varied, so that the multi-sided containers may have more than four sides. In some embodiments, there may be so many sides that the multi-sided containers are substantially cylindrical.

It may be advantageous for the conductive material **22** of an access diode to wrap at least partially around the memory element material of a cross-point memory cell to improve coupling between the diode and the memory element material. Accordingly, the wrapping access structures formed in accordance with the embodiments of FIGS. **24-48** (for instance, the structure shown in FIG. **36**) may have some advantages relative to the planar diode structures formed by the embodiment of FIGS. **1-23** (with such planar structures being shown in FIG. **23**). However, the embodiment of FIGS. **1-23** may have an advantage in some applications in that the processing of the embodiment of FIGS. **1-23** may be simpler than the processing of the embodiments of FIGS. **24-48**.

In compliance with the statute, the subject matter disclosed herein has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the claims are not limited to the specific features shown and described, since the means herein disclosed comprise example embodiments. The claims are thus to be afforded full scope as literally worded, and to be appropriately interpreted in accordance with the doctrine of equivalents.

We claim:

- 1.** A method of forming a memory array, comprising: forming first electrode material over a base; forming a memory cell stack over the first electrode material; the memory cell stack including, in ascending order from the first electrode material, a first insulator material, at least one additional insulator material, an electrically conductive material, and memory element material; patterning the first electrode material and the memory cell stack into a first set of spaced lines extending primarily along a first horizontal direction; forming dielectric material between the spaced lines of the first set; forming spaced lines of second electrode material over the first set of spaced lines and over the dielectric material, the lines of second electrode material being a second set of spaced lines and extending primarily along a second horizontal direction that is orthogonal to the first horizontal direction; and removing memory element material and electrically conductive material of the memory cell stack from regions between the lines of the second set to leave an array of memory unit cells, individual memory unit cells comprising the memory cell stack between the first electrode material and the second electrode material.
- 2.** The method of claim **1** wherein the removing of the memory element material and the electrically conductive material of the cell stack occurs before forming the spaced lines of the second electrode material.
- 3.** The method of claim **1** wherein the removing of the memory element material and the electrically conductive material of the cell stack occurs after forming the spaced lines of the second electrode material.
- 4.** The method of claim **1** wherein the spaced lines of second electrode material are formed directly over the first set of spaced lines of the memory cell stack and utilized as an electrically conductive hard mask during the removing of the memory element material and the electrically conductive material of the memory stack.

14

- 5.** The method of claim **1** further comprising: forming a patterned mask over the first set of spaced lines and over the dielectric material, the patterned mask comprising spaced lines extending primarily along the second horizontal direction; and forming the second electrode material within spaces between the spaced lines of the patterned mask to thereby form spaced lines of second electrode material.
- 6.** The method of claim **5** wherein the dielectric material is a first dielectric material, and further comprising, after forming the second electrode material, replacing the spaced lines of the patterned mask with a second dielectric material.
- 7.** The method of claim **6** wherein the second dielectric material is a same composition as the first dielectric material.
- 8.** The method of claim **5** wherein the second electrode material is initially formed over the spaced lines of the patterned mask as well as between the spaced lines of the patterned mask, and further comprising planarizing the second electrode material to remove the second electrode material from over the spaced lines of the patterned mask, while leaving the second electrode material between the spaced lines of the patterned mask.
- 9.** The method of claim **5** wherein the patterned mask is a second patterned mask, and wherein the patterning of the first electrode material and the memory cell stack into the first set of spaced lines, comprises: forming a first patterned mask over the memory cell stack, the first patterned mask comprising a plurality of spaced lines extending along the first horizontal direction; and transferring a pattern from the first patterned mask through the memory cell stack and the first electrode material with one or more etches.
- 10.** The method of claim **9** wherein the first patterned mask remains over the first set of lines as the dielectric material is formed between the spaced lines of the first set.
- 11.** The method of claim **9** wherein the first patterned mask comprises one or more of amorphous carbon, transparent carbon, silicon dioxide, silicon nitride and silicon oxynitride.
- 12.** The method of claim **11** wherein the second patterned mask comprises one or more of amorphous carbon, transparent carbon, silicon dioxide, silicon nitride and silicon oxynitride.
- 13.** The method of claim **1** wherein: the first electrode material has a low work function relative to the electrically conductive material of the memory cell stack, the first electrode material comprises one or more compositions selected from the group consisting of tantalum silicon nitride, chromium and tantalum, and the electrically conductive material of the memory cell stack comprises one or more compositions selected from the group consisting of platinum, titanium nitride and tantalum nitride.
- 14.** The method of claim **1** wherein one or more other components of the memory cell stack are removed from between the spaced lines of the second set in addition to the memory element material and the electrically conductive material.
- 15.** The method of claim **1** wherein the only components of the memory cell stack that are removed from between the spaced lines of the second set are the memory element material and the electrically conductive material.
- 16.** A method of forming a memory array, comprising: forming a substrate to comprise a plurality of spaced apart lines of first electrode material, and to comprise trenches directly over the spaced apart lines and in one-to-one

15

correspondence with the spaced apart lines; the trenches and the lines of first electrode material extending along a first horizontal direction;

forming access device materials within the trenches to partially fill the trenches and thereby narrow the trenches, the access device materials including an electrically conductive metal-containing material and at least two insulative materials, the insulative materials being between the electrically conductive metal-containing material and the first electrode material;

forming memory element material within the narrowed trenches, the memory element material forming a plug that extends into the access device materials, and the access device materials extending along a bottom and two sides of the memory element plug, the memory element material being configured as a plurality of spaced apart lines in one-to-one correspondence with the trenches;

forming second electrode material over the memory element material lines and over regions between the spaced apart memory element lines;

forming a patterned mask over the second electrode material, the patterned mask comprising a plurality of spaced apart lines, the spaced apart lines of the patterned mask extending along a second horizontal direction that is orthogonal to the first horizontal direction of the lines of first electrode material; and

transferring a pattern from the patterned mask through the second electrode material, through the memory element material and through the access device materials to thereby pattern the access device materials and memory element material into array of memory cells, and to pattern the second electrode material into top electrode lines extending over the memory cells and orthogonally to the lines of first electrode material.

17. The method of claim 16 wherein the access device materials are initially formed within the trenches to comprise sidewall regions along sidewalls of the trenches, and to comprise bottom regions along bottoms of the trenches; and further comprising recessing the sidewall regions of the access device materials to a level beneath an upper level of the trenches prior to forming the memory element material.

18. The method of claim 17 wherein the recessing forms a planarized upper surface across the access device materials.

19. The method of claim 16 wherein the patterned mask is a second patterned mask, and wherein:

- the substrate comprises a base and a first patterned mask over the base;
- the first patterned mask comprises a plurality of spaced apart lines; and
- the trenches correspond to gaps between the spaced apart lines of the first patterned mask.

20. The method of claim 16 wherein the patterned mask is a second patterned mask, and wherein the forming the substrate comprises:

- forming a first patterned mask over a base, the first patterned mask comprising a plurality of spaced apart lines, the spaced apart lines being separated from one another by gaps;
- etching into the base to extend the gaps into the base; and
- filling a lower region of the gaps with the first electrode material to form the lines of the first electrode material, and leaving an unfilled upper region of the gaps as the trenches over the lines of the first electrode material.

21. A method of forming a memory array, comprising:

- forming a substrate to comprise a plurality of spaced apart lines of first electrode material, and to comprise a plu-

16

rality of polygonal openings directly over the lines of first electrode material; the polygonal openings being in many-to-one correspondence with the lines of first electrode material; the lines of first electrode material extending along a first horizontal direction;

forming access device materials within the openings to partially fill the openings and thereby narrow the openings, the access device materials including an electrically conductive metal-containing material and at least two insulative materials, the insulative materials being between the electrically conductive metal-containing material and the first electrode material;

forming memory element material within the narrowed openings, the memory element material within each individual opening forming a plug that extends into the access device materials, and the access device materials within each individual opening extending along a bottom of a memory element plug and around three or more sides of the memory element plug, the memory element material being configured as a plurality of spaced apart structures in one-to-one correspondence with the openings;

forming second electrode material over the memory element material structures and over regions between the spaced apart memory element structures;

forming a patterned mask over the second electrode material, the patterned mask comprising a plurality of spaced apart lines, the spaced apart lines of the patterned mask extending along a second horizontal direction that is orthogonal to the first horizontal direction of the lines of first electrode material; and

transferring a pattern from the patterned mask through the second electrode material to pattern the second electrode material into top electrode lines extending over the memory element material and orthogonally to the lines of first electrode material.

22. The method of claim 21 wherein the access device materials are initially formed within the openings to comprise sidewall regions along sidewalls of the openings, and to comprise bottom regions along bottoms of the openings, and further comprising recessing the sidewall regions of the access device materials to a level beneath an upper level of the openings prior to forming the memory element material.

23. The method of claim 22 wherein the recessing forms a planarized upper surface across the access device materials.

24. The method of claim 21 wherein the patterned mask is a third patterned mask, and wherein:

- the substrate comprises a base, a first patterned mask over the base, and a second patterned mask over the first patterned mask and over the base,
- the first patterned mask comprises a plurality of spaced apart lines extending primarily along the first horizontal direction;
- the second patterned mask comprises a plurality of spaced apart lines extending primarily along a second horizontal direction that is orthogonal to the first horizontal direction; and
- the openings correspond to overlapping gaps between the spaced apart lines of the first patterned mask and between the spaced apart lines of the second patterned mask.

25. The method of claim 21 wherein the patterned mask is a third patterned mask, wherein the forming the substrate comprises:

- forming a first patterned mask over a base, the first patterned mask comprising a plurality of spaced apart lines,

17

the spaced apart lines extending primarily along the first horizontal direction and being separated from one another by first gaps; etching into the base to extend the first gaps into the base; filling a lower region of the gaps with the first electrode material to form the lines of the first electrode material, and leaving an unfilled upper region of the first gaps as trenches over the lines of the first electrode material; and forming a second patterned mask over the first patterned mask and the base, the second patterned mask comprising a plurality of spaced apart lines, the spaced apart lines of the second patterned mask extending primarily along a second horizontal direction that is orthogonal to

18

the first horizontal direction and being separated from one another by second gaps, and regions where the second gaps overlap with the first gaps being the polygonal openings.

5 **26.** The method of claim **25** wherein the first and second patterned masks comprise one or more of amorphous carbon, transparent carbon, silicon dioxide, silicon nitride and silicon oxynitride.

10 **27.** The method of claim **25** wherein the polygonal openings comprise four sides.

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